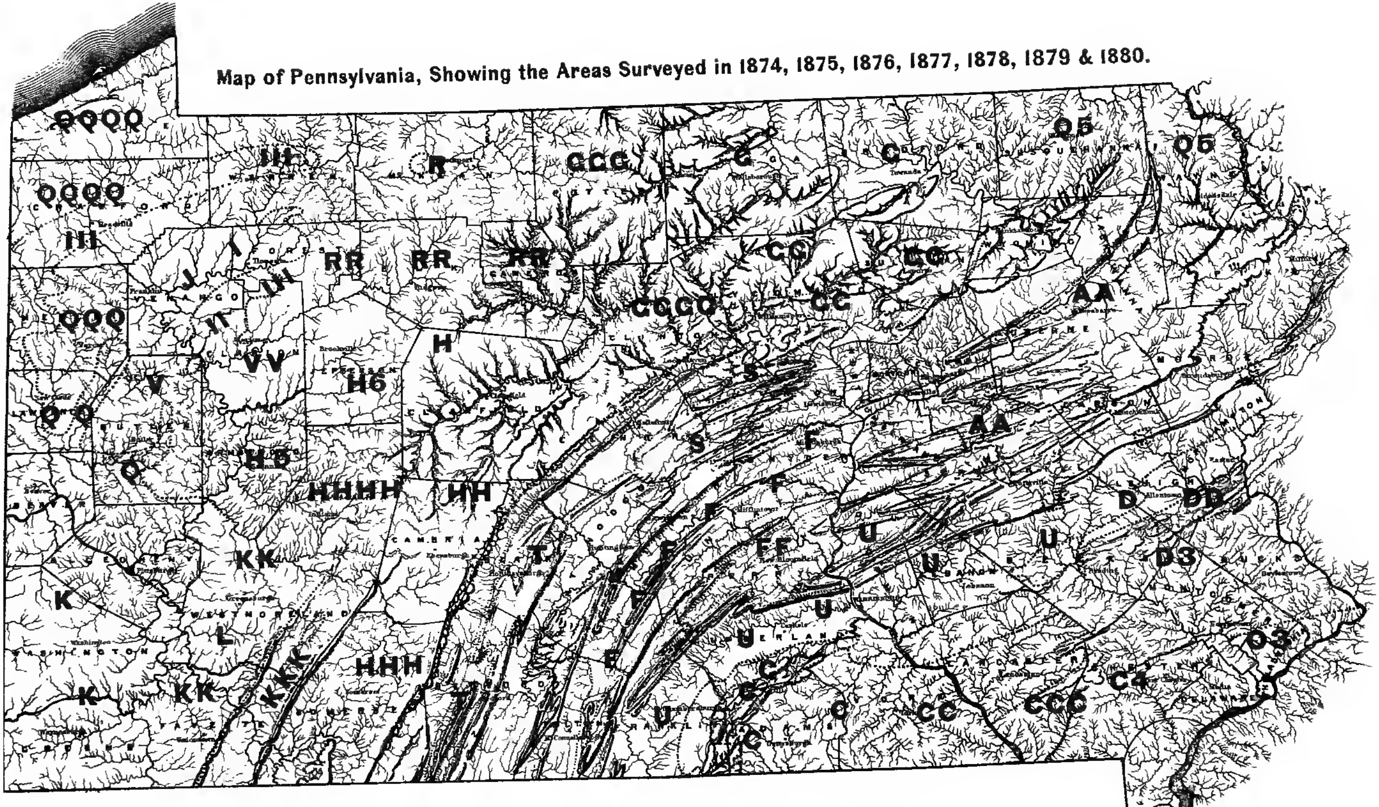
Map of Pennsylvania, Showing the Areas Surveyed in 1874, 1875, 1876, 1877, 1878, 1879 & 1880.



SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA:

REPORT OF PROGRESS

D^3, VOL. I.

THE GEOLOGY OF

LEHIGH AND NORTHAMPTON COUNTIES.

GENERAL INTRODUCTION BY J. P. LESLEY.
SLATE BELT AND QUARRIES BY R. N. SANDERS.
WATER GAPS BY H. M. CHANCE.
LIMESTONE BELT AND IRON ORE MINES BY F. PRIME.
SOUTH MOUNTAIN ROCKS BY F. PRIME.
ITINERARY SURVEY OF THE MOUNTAINS BY C. E. HALL.

WITH NUMEROUS PAGE PLATE ILLUSTRATIONS,
3 LITHOGRAPH AND 3 ARTOTYPE VIEWS OF QUARRIES
AND AN ATLAS
CONTAINING
A COLORED CONTOUR MAP OF SOUTHERN NORTHAMPTON ON 6 SHEETS,
A CONTOUR MAP OF THE MOUNTAIN REGION ON 17 SHEETS,
A COLORED GEOLOGICAL INDEX MAP ON 1 SHEET,
A COLORED GEOLOGICAL MAP OF NORTHAMPTON AND LEHIGH COUNTIES; AND
4 MAPS OF IRON MINES IN BERKS COUNTY.

HARRISBURG:
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FOR THE SECOND GEOLOGICAL SURVEY.
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PREFATORY LETTER.

To His Excellency ROBERT E. PATTISON, *Chairman, ex-officio, of the Board of Commissioners of the Second Geological Survey of Pennsylvania:*

SIR: I have the honor to present for your consideration the report of the progress of the survey in Northampton, Lehigh and Berks counties, noted in the series as D^3.

The geological survey of Northampton and Lehigh counties was commenced by Prof. Prime in 1874, and continued by him until 1878.

A report (D) of the progress of the work was published in 1875, and another (DD) in 1878. That of 1875 described ninety-eight iron ore mines in the limestone country west of the Lehigh. Their locations were shown on a contoured map of a part of the district.

With Report DD was published a four-sheet contour map of the limestone valley land in Lehigh county. On this map were located 202 mines. A fifth sheet gave a detailed map of the Ironton mines on a large scale.

After 1878, the topographical survey of the limestone valley land was carried on without interruption, first eastward through Northampton county to the Delaware river, and then westward through Berks county to the Schuylkill river, where it stopped.

This survey of the limestone valley land was carried to the top of the first range of slate hills along its northeast border; and up the first slopes of the South Mountains along its southern border.

In 1879, 1880, 1881, and 1882, it was further extended south-westward to embrace the whole South Mountain region: the Durham hills, the Reading highlands, Durham, Saucon, Oley and other interior limestone valleys, the belt

of limestone south of the mountains, and the edge of the Mesozoic red sandstone, shale, conglomerate and trap country along the Bucks and Montgomery line. Meanwhile, Mr. Sanders made a special topographical survey of the narrow belt of trap, etc., south of Reading and west of the Schuylkill river, which is included in the map.

In the spring of 1880 six sheets of this survey were prepared and printed in colors, to illustrate a report on Northampton county. They constitute a map by themselves, showing the limestone region of the lower Lehigh and Delaware rivers, and the mountains as far south as an east and west line cutting the Saucon creek near its mouth. A part of the previously published map of Lehigh county is reproduced on this map to make its south and west borders conterminous with the other sheets of the survey.

These six special Northampton county sheets, and the sheets of the mountain survey which fit on to them, on the south and west, are now published in an Atlas to Report D³, Vol. I, on Lehigh and Northampton counties, and Vol. II on Berks county.*

Also, in this Atlas will be found the seventeen sheets of the mountain survey, embracing the Reading hills and limestone valley in Berks county, as far as the Schuylkill river, on a scale of 1,600 feet to an inch, the contour lines 10 feet vertically apart.

Also, an Index Map of the whole survey, on the scale of two miles to an inch, geologically colored.

Also, a colored geological map of Lehigh and Northampton counties, on the scale of two miles to the inch, like the maps of the other counties of the State.

The six-sheet map embraces the townships of Allen, E. Allen, Upper Nazareth, L. Nazareth, southern Lower Mt. Bethel, Forks, Easton, Palmer, Bethlehem, northern Williams, and northern Lower Saucon in Northampton county; with Hanover and eastern Salzburg in Lehigh county.

All the field work was plotted on 400′ : 1″, and reduced to 1600′ : 1″.

Contour lines 10′ apart; the hundred-foot lines are des-

* Now going through the press, June, 1883.

ignated in many places. The *heights above tide* of most of the hill tops, and sink-hole bottoms, are given. The levels of RR. grade at RR. stations, published in Report N, were accepted as data.

An error of 30′, in that part of the Lehigh map of Report DD lying east of the river, is corrected in this map of Report D^3.*

Most of the surveying was done with a Heller & Brightly mining transit, and stadia measurements. A few small inside circuits were paced. The topography to the right and left of lines run was sketched in the field note-book.

Arrows show the direction of the *dip*, where bed-rock was observed. The cross lines to the arrows show the *strike* or course of the rock across country. The figures give the *angle of dip* to the horizon.

The numbering of the iron mines corresponds with that of the list given on the south-east blank corner of the map.

On the colored Geological county map of Lehigh and Northampton have been placed the slate quarries, numbered as described by Mr. Sanders in Chapter II of this report. The dips are also shown by arrows.

Mr. Chance's large contoured maps of the Delaware and Lehigh water gaps have been published in Mr. White's report, G^6 on Pike and Monroe counties, most of their rocks belonging to that region, although these maps extend southward into the slate region described in this report, as shown by the sections on pages 155, 157, 159, of Mr. Chance's description, commencing on page 148. On these local maps some of the most important slate quarries are situated.

It is to be regretted that topographical work of this kind is so tedious and expensive that the resources of the State Survey were inadequate for the extension of the survey of the limestone belt northward over the wide slate belt to the Kittatinny mountain. Seven years of almost uninterrupted field and office work were required for mapping southern Northampton and Lehigh and eastern Berks counties. The

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* All the contour lines on the 4-sheet Lehigh map *east of the river* are marked 30′ too high above tide. The error was made at starting from the Catasauqua bridge. The contours on both maps are alike.

slate belt between the Delaware and the Schuylkill could not be thus surveyed in less than five years. Nor would the utility of such a survey justify the expense of time and money out of the limited appropriations to the State Survey,—except along the roofing slate range at the foot of the mountain. The location of the quarries by Mr. Sanders on the county maps will, however, suffice for all practical purposes at present; but a special topographical survey of this range should be undertaken.

As for the South Mountain region, there was no escape from the necessity of a complete hypsometrical survey, cost what it might. The geological structure can be made out in no other way; and the map sheets now published will be in all future time a basis of local exploration. Without such a map any exploration must be done in the dark.

I had prepared for this Volume a discussion of the phenomena of *roofing slate cleavage*, with its relationship to the subject of the former extension over and subsequent erosion of the Silurian and Devonian formations from off the area of the State now occupied by the Great Valley; but the long delay already caused by the slow completion of the maps makes it necessary to postpone its publication to the second volume of D[3].*

Other matter connected with the slate belt will find place in the report on that part of it which traverses Berks county.

The alleged nonconformity of Formation No. IV, (Oneida and Medina sandstone,) on Formation No. III, (Hudson river slate,) does not appear in Pennsylvania. It will be seen by reference to Mr. Sanders' exposure No. 131 (on page 112) that the slates graduate into sandstone upwards, towards the conglomerate which overlies them, after a concealed interval (at that place) of less than fifty feet. There is no nonconformity at the Delaware water gap, nor at the Lehigh gap. In the Berks county report it will be shown how, at the Schuylkill water gap, the sandstone beds lie transversely at right angles upon the edges of the slate, not

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* Twelve chapters of which are going through the press, June, 1883.

by reason of any nonconformity in deposition, but by reason of a fault or snapped anticlinal, which is traceable for some miles, and dies out at each end. The section is given on page 153. The edge of the slate is ground smooth by friction. No trace of erosion is visible, such as must have appeared if the sandstones of IV had been deposited on a previously-exposed surface of the upturned slates of III. The presence of *supposed* fragments of III in the rocks of IV, at the Delaware water gap, is no evidence of nonconformity of IV upon III at that locality, because—1. to create such fragments III would have to be eroded at or near that locality, and there is no sign of such erosion; 2, because the fact of IV being outspread over hundreds of miles shows the extent of the sea in which it was deposited; consequently the distance of its shores from that locality; consequently the improbability of the transport of such fragments such a distance. But if the fragments be really fragments of III (which is not proved) and came from a distant shore, that fact alone suffices to disprove the supposed nonconformity at that locality. The fact is, any nonconformity between III and IV, or III and VI, observed at Rondout in New York, must be a local phenomenon not affecting the rest of the Appalacian region. My views on this subject will be found on page 32.*

Photographs of several slate quarries were taken by Mr. E. B. Harden, who is very skillful in selecting points of view best calculated for enriching the reports of his fellow assistants on the Survey with pictorial illustrations of important geological features difficult to describe textually. Three views of the quarries at Slatington have been reproduced (from his negatives) by the *Artotype process* of Mr. Bierstadt, of New York.

Old Quarry No. 2, James Hess & Co. (No. 155,) shows two features of prime importance: 1. *The thickening of a slate stratum by pressure* in the jaw of a synclinal; 2. The

* Such an instance is narrated by Mr. White on page 150 of his Report G⁶, on Pike and Monroe counties, as occurring at Otisville in northern New Jersey, on the line of the Erie railroad, a number of miles east of the extreme point of Pennsylvania, and nearly 50 miles east of the Delaware water gap.

development of the cleavage by pressure, at angles to the axial plane of the synclinal which *differ in the different beds*, and on the two sides of the synclinal.

The relation of the *cleavage* to the *fault* is shown in the picture of the American slate quarry No. 2, (No. 159.)

The picture of the American slate quarry No. 1, (No. 159,) displays the extent to which the rock is quarried at various places in the region.

Mr. Sanders reported to me a list of quarries which ought to be photographed to show these and other features of the geology of the belt; but the business of the survey combined with bad weather to defeat my arrangements for having these taken. The list may be useful to other geologists, and some of the points may be photographed before the publication of the second volume :—

Jurry's quarry at Pen Argyl (No. 39) shows the cleavage of the slate *at right angles to the axial plane of a synclinal.*

Peter Fry's quarry, (No. 6,) two miles north of Portland; the Bangor quarry, (No. 21,) at Bangor; the Bangor union quarry, (No. 23;) the North Bangor quarry, No. 3, (No. 26,) at Bangor; the True Blue quarry, (No. 29,) two miles south of Bangor; and the Star quarry, (No. 195,) two miles north of Steinsville—all show the slate cleavage *parallel to the axial plane of a synclinal.*

The Blue Mountain quarry, (No. 157,) at Slatington, shows *a rolling structure with the slate cleavage uniform throughout.*

The Bangor quarry, (No. 21,) at Bangor, presents a remarkable aspect to the spectator approaching its north-west corner. The bed planes appear to form concentric ovals. This curious optical illusion is produced by the angles of the quarry penetrating the body of an *overthrown collapsed synclinal.*

The Snowden quarry, (No. 5,) two miles north of Portland, shows a *fault* with the slates curved above it, and the cleavage on each side.

Chapman's quarry, (No. 79,) at Chapman Station, would furnish an excellent *general view* of the methods employed

in working a large quarry. Here, perhaps, could be best procured a picture of a *cable derrick*, with its frame and traveller, slate-dressing tools, chisels, dressing machines, &c., &c.

The occurrence of No. III (Hudson river) slates at Limeport, in the South Mountain region, observed by Mr. Hall, and described on page 257 of this report, is of great importance. It deserves the careful consideration of any geologist who doubts the former extension of the Palæozoic formations across the present area of the Azoic rocks, southeastward, towards the Atlantic ocean;—of any geologist who is disposed to assume the existence of an Oneida or Medina sea-shore somewhere along the present South Mountain-Blue Ridge range;—of any geologist who hesitates to believe that the erosion of that range commenced after the Coal age.

The limestone belt of Northampton county is described by Prof. Prime in Chapter III. The numerous dip arrows on the six-sheet map will furnish a basis of future investigation into the very obscure structure of this complicated region. I made an only partially successful effort to represent *by underground contours* the interrupted anticlinal which runs across the county south of the slate belt. It is not in a satisfactory shape to appear in the first volume of this report, and must be withheld in view of a general discussion of the Great Valley in a future report.

A local contour sketch map of the Jerusalem church gap of the Little Lehigh river in Lehigh county, is also reserved for the second volume (on Berks county), as it bears upon the question of the superposition of the limestone and Potsdam sandstone up on the gneiss.

Iron ore mines are rare in the limestone belt of Northampton county, which accounts for the few analyses of limonite ores in this report.

Mr. A. S. McCreath reported to me, January 11, 1883,

that he had made 102 *analyses* for Report D[3], as follows: Iron ores, 61; limestones, 40; kaolin, 1.

Some of these will appear in Vol. 2, as belonging to mines and quarries in Berks county, samples from which were taken by Mr. McCreath himself in July and August, 1881. "Magnetic iron ores vary so much from time to time in their yield of metallic iron that a reference to the date of sampling is necessary."

In Prof. Prime's report of the progress of surveys in Lehigh county in 1875–6 (D[3], 1878) *analyses of iron ores* from the Brown, Ironton, Henninger's, Boyer's, Seeger's, Levan's, Guth's, Weaver's, Kline's, Sheifer's, Ruch's, Biery's, Roth's, Jobst's, Schwartz's, Daney's, Keck & Ritter's, Trexler & Kline's, H. Kline's, J. Kline's, and Seam's mines are given on pp. 25 to 48.

In Mr. McCreath's report of the work of the Laboratory at Harrisburg for 1876–7–8, MM., 1879, these analyses are given on pages 213 to 217. Also, analyses of ores from the Ritter, Glick, Kehm, Schneider, Kurtz, M. Mory, and G. and W. Mory mines in Lehigh county, and the Saucon Iron company's mines in Northampton county; pp. 213, 215, 217, and 218. These I here insert:

Lehigh county.

	(61) Ritter.	*(62) Ritter.*	*(357) Glick.*	*(358) Kehm.*
Iron,	39.300	47.700	49.500	53.000
Manganese,	.065	2.958	.194	.216
Sulphur,	.008	.049	.019	.024
Phosphorus,	1.269	.328	.102	.096
Insoluble residue,	28.195	12.595	13.410	7.290

(*61*) *P. Brown's mine* at Ironton; *lump ore*; compact, rather fine-grained, dark brown.

(*62*) *P. Brown's mine; lump and wash ore*; compact, arenaceous, dark brown. (D. McCreath.)

(*357*) *Charles Glick's mine*, 3½ miles N. W. of Emaus; leased by Allentown Iron Company; *lump ore;* compact, also cellular, with considerable adhering clay; dark brown.

(*358*) *Solomon Kehm's mine*, 2½ miles N. W. of Emaus;

lump ore; hard, compact and tough; carries some particles of quartz and considerable adhering clay.

Lehigh County.

	(968.) Schneider.	(969.) Kurtz.	(970.) M. Mory.	(981.) G. & W. Mory.
Sesquioxide of iron,	64.428	75.714	68.785	47.000
Sesquioxide of manganese,	.982	.228	.207	.889
Sesquioxide of cobalt,	.040	.010	.020	.080
Alumina,	2.108	1.421	2.974	3.696
Lime,	.170	.160	.120	.100
Magnesia,	.288	.288	.288	.418
Sulphuric acid,	.032	.447	.612	.062
Phosphoric acid,	1.104	1.175	.941	.584
Water,	11.374	12.724	12.866	8.622
Insoluble residue,	19.760	7.790	13.310	38.940
	100.286	99.957	100.123	100.391
Metallic iron,	45.100	53.00	48.150	32.900
Metallic manganese,	.684	.159	.144	.619
Sulphur,	.013	.179*	.245†	.025
Phosphorus,	.482	.513‡	.411	.255

(*968*) *David Schneider's mine*, three miles from Friedensville, and seven miles south-west from Hellertown. *Lump and wash ore.* Leased by Saucon Iron Co. Generally compact and fine-grained, with considerable bomb shell ore, the walls of the bombs being lined with dark brown fibrous iron oxide.

(*969*) *Widow Kurtz's mine*, near Friedensville, and four miles south-west from Hellertown. *Pipe ore.* Leased by Saucon Iron Co. Cellular, pipe ore, generally of a dark brown color.

(*970*) *Morgan Mory's mine*, near Friedensville, and four miles south-west of Hellertown. *Lump and wash ore.* Leased by Saucon Iron Co. Brittle, cellular; the cells for the most part filled with ocherous iron ore. Color, light and dark brown.

(*981*) *G. and W. Mory's mine*, near Friedensville, and four miles south-west from Hellertown. *Lump and wash ore.* Leased by Saucon Iron Co. Cellular, brittle, with

* Duplicate sulphur determination gave .179.
† Duplicate sulphur determination gave .246.
‡ Duplicate phosphorus determination gave .514.

considerable ferruginous clay and free quartz. Color of ore, dark brown to yellow brown.

Northampton County.

Saucon Iron Company.

	(980.)	(967.)
Sesquioxide of iron,	49.928	63.714
Sesquioxide of manganese,	7.358	.455
Sesquioxide of cobalt,	.140	.040
Alumina,	3.053	1.090
Lime,	.110	.180
Magnesia,	.418	.324
Sulphuric acid,	.042	.027
Phosphoric acid,	1.169	.836
Water,	11.384	11.980
Insoluble residue,	26.700	21.940
	100.302	100.586
Metallic iron,	34.950	44.600
Metallic manganese,	5.123	.317
Sulphur,	.017	.011
Phosphorus,	.509	.365

(*980*) *Wharton mine of Saucon Iron Co.*, two miles east from Hellertown. *Specimens from higher level, about eighty feet deep. Lump and wash ore.* Compact, brittle, sandy; dark brown to reddish brown.

(*967*) *Wharton mine of Saucon Iron Co.*, two miles east from Hellertown. *From deep shaft, 126 feet under ground. Lump and wash ore.* Hard, tough, fine grained; color, liver brown.

Analyses of the Crane Iron Company's mine by Mr. Gayley; of the Ironton mines by Mr. Pemberton; and of the Brown mine by Mr. Britton, are given in Report D[2], on pages 37, 42, and 46.

The *Glacial Drift* so finely exhibited in the north-eastern corner of Northampton county is only incidentally mentioned in this report, because it will be fully described in Prof. H. C. Lewis' report X on the Terminal Moraine in Pennsylvania, now ready for the press. This heterogeneous mass of sand, gravel, and bowlders of all sizes, crosses the State of New Jersey from Amboy to Belvedere. On the western side of the Delaware it sweeps a curve west and north to

Offset Valley creek ; ascends the mountain near Tot's gap ; crosses the summit and descends into the back valley in Monroe county. Huge masses of the Monroe county rocks have been carried by the ice over the mountain and been dropped on its southern slopes in Northampton county. The surface of Upper Mt. Bethel county, lying behind the moraine, differs from that of the rest of the county because the old slate surface is now covered with a deep, irregular coating of drift, such as overspreads eastern and northern Monroe, all Pike, Wayne, Susquenanna, and other northern counties as far west as McKean.

Much material for the study of this interesting subject will be found in Reports G^5 and G^6 ; but the reader should prepare himself for comprehending glacial phenomena by a careful study of Prof. Geikie's book entitled The Great Ice Age, and Prof. I. D. Whitney's great work on the California gravels, and on Climatal Changes in the earth's history.* Glacial literature is already very copious ; books and memoirs over names of high authority are numerous ; but I caution the geologists of Pennsylvania against views in vogue respecting the great erosive power of glacial ice ; for, if they be accepted as true, our well-studied conclusions respecting the origin of our mountains and valleys would fail. In Northampton county we have, perhaps, a unique case of the possibility of actually *guaging in feet the exact amount of eroding work which ice can do ;* and by this case the worth, or rather worthlessness, of the popular exaggerations can be tested ; thus—

The crest of the Kittatinny mountain is of remarkably uniform height and character for two hundred miles across the State ; always sharp and rocky ; with a long northern and a steep southern slope, set with low sandstone cliffs. But at four miles west of the Delaware water gap a change occurs ; the mountain crest is, from this point eastward, not sharp and rocky, but rounded and smooth enough to be cultivated. The point where the change takes place is the point where the Terminal Moraine crosses the top of the mountain. The ice-sheet, which advancing from the N. E.

* Published early in 1883.

dropped the moraine, smoothed off the sharp rugged crest of the mountain; and the difference of height—about 70 feet—between the crest south-west of the moraine and north-east of the moraine shows exactly how much work the ice was able to do, operating upon this massive outcrop of sandstone and conglomerate. If the ice had moved from the north-west instead of from the north-east—and if it had merely reached the top of the mountain, and melted away on its southern slope—it might be said the facts were merely a test of the *minimum* ability of the ice-sheet; but since the ice-sheet moved diagonally across the mountain and extended far into the low country (as the Beldevere section of the moraine shows) there can be no doubt that the erosion of the top of the mountain was as great as the ice-sheet could perform anywhere in Pennyslvania;* and the fact that it amounted to only about 70 feet disperses the popular poetic fiction of ice-excavated Great Lake basins and Appalacian valleys.

The practical character of the Geological Survey of Pennsylvania has not been dictated merely by the policy of supplying the citizens of the State first and foremost with facts, and leaving to irresponsible individuals the invention of as many theories of the facts as they please; but by an honest and deep distrust of the value of most of the glittering generalities, or generalizations as they are commonly called, which the younger, and some of the elder geologists seem to consider the best part of the geological work of the day. The great laws of geology were discovered, proved, and put in force years ago. These laws are sound and reliable, and all our interpretations of observed facts are referred to them and tested by them. But many of the recently invented generalizations, so far from having been yet engrossed among the laws of the science, are merely the vague and often fanciful suggestions of half educated and undisciplined minds, filled with zeal, endowed with talent, but insuffi-

* The supposed greater thickness of the ice-sheet further north is no argument for a greater power of erosion; for, in spite of the popular opinion to the contrary, it can be easily shown that the thickness (*i. e.*, the weight) of a glacier has nothing to do with its erosive power.

ciently furnished with knowledge, prompted by an ambition for personal renown which they often mistake for a love of truth, and impatient of the tedious labor which a rigid mathematical and pictorial criticism of facts imposes on the sober geologist. Every now and then it is announced that a new era in geological science has commenced; that a new method of investigation has been discovered which is to supersede the old methods; that a new principle has been obtained by which the vexed questions of deposition, elevation, depression, erosion, metamorphism and classification can be settled. A few years, sometimes a few months, suffice to dispel the illusion and vitiate the prophecy

Among these fugitive visions has appeared an hypothesis, just now much in vogue, that the *weight of ice* in the glacial period has played a masterly role in the structural history of the earth. To an experienced geologist accustomed all his life to measuring everything relating to the crust of the earth, first in detail and then in the gross, it is hardly necessary to point out the absurdity of ascribing work to a plate of ice, with a specific gravity of 1, which mountain masses of rock, with the specific gravity of nearly 3, have not been able to perform. The tertiary plateau of Asia, the tertiary dome of the Rocky Mountains, could hardly remain above sea level, if 3000 feet of *ice could depress the area* over which it lay, and by its melting away allow that area to float up again to its original altitude. One thousand feet of Laurentian gneiss, limestone, and trap weigh as much as 2700 feet of ice. Yet the Canadian highlands stand firm at 2000 feet above tide, weighing as much as the ice that once covered them did on the unproved supposition that it was not 3000 but 5500 feet thick. And yet upon this fancied movement of the earth crust downwards when overcome by ice, and upwards when relieved by its disappearance, one so-called "theory" of the general southward slope of the formations through New York and Pennsylvania towards the Kittatinny valley has been based.

It is right that the citizens of Pennsylvania should know that good geologists feel the same distrust of geological theories, floated on the authority of popularly great names,

that they do for extravagant statements respecting mineral wealth floated on the reports of popularly famous experts.

The study of the Alpine glaciers and their moraine deposits was commenced by Agassiz and his disciples as long ago as 1835, and has been sedulously prosecuted by Swiss, French, and Italian geologists ever since. Nearly fifty years of work have not sufficed to overcome all the difficulties encountered in the progress of the investigation, and the last discoveries of Fabre and Desor throw new light upon the age, extent, and order of the deposits.

The Glacial Geology of Great Britain virtually came under investigation in 1847, when Agassiz first awoke the English and Scotch geologists to its importance. Thirty-five years have been spent by hundreds of most accomplished and zealous field workers in the examination of every mountain, valley, and plain in the British islands, in collating innumerable railway cuts, ravines, shafts and wells with off-shore soundings,—in discussing the bowlders, gravel, sand, and clay of the till, to distinguish them from those of the shore and river deposits,—and in searching for fossil plants, shells, and animal remains to determine the probable unity, duality, or multiplicity of the ice movement; the possible submergence and emergence of land meanwhile; the presence or absence of mankind; the formation of lakes and new rock cuts by the ice; and the total effect upon the topography of that part of Europe. Yet one has only to read the current descriptive, theoretical, and controversial literature of English Geology to see that the end of this long investigation is far from being reached.

In Pennsylvania the same kind of minute and universal study of glacial phenomena is needed; and young geologists, now in our schools of science, will find their zeal and diligence taxed to the utmost for twenty years to come, to give a true account of the origin of the ice sheet—its thickness, its course, its advances and retreats, its effects upon the surface, where it picked up its burden of trash, and where and how it distributed the materials; whether the forest, destroyed by a first invasion of the ice, grew again before a second invasion; whether successive flows of ice

differed as to the extent of country they covered, and which one of them it was that left its mark in the Great Terminal Moraine; whether the sea level fell so as to leave the present Atlantic soundings dry; or rose, so as to flood the continent to or far above the level of the Lafayette College grounds on Easton hill; or rose and fell alternately during the long continuance of the Glacial Age; and how the rivers have varied in volume and force; and what are the relative ages and distinctive characters of the *readjusted drift* on the upland and in the valleys.

The State Geological Survey, with all its other work on hand, can only indicate in its Reports of Progress these subjects of future investigation, and mark out in outline the great facts which will be studied in detail by Pennsylvanians when their interest in this branch of science has been aroused.

In England, most of the final results have been reached by private organizations called Field Clubs; and this may happen in the United States. Much can be done by parties of college students in vacation; but the most of the work will be accomplished by intelligent private citizens of the State, each studying the district in which he happens to live, and communicating his observations to some society which publishes Proceedings. There should be a society of local investigators, a field club of naturalists, in every county in Pennsylvania, which could easily place itself in active correspondence with the American Philosophical Society, or with the Academy of Natural-Sciences in Philadelphia, for the publication of their papers, or they might place them at the disposal of a geological bureau at Harrisburg for publication by the State.

Such societies already exist at Wilkes-Barre, at New Bloomfield in Perry county, at Lancaster, at Media in Delaware county, and at Johnstown in Cambria county. Greensburg in Westmoreland county was once a famous center of scientific activity. Meadville, Washington, Bellefonte, Bethlehem, Easton, Gettysburg, Mercersburg and other towns have colleges and normal schools which would make nuclei around which scores of intelligent observers could group themselves. The genius of our century is one

of fruitful association. Natural science is now too copious and difficult to be managed by isolated seekers after truth; its devotees must arrange themselves into communicating groups. The history of science in England shows how much more knowledge is gained by a multitude of small corresponding societies, than by a few metropolitan academies of science. These last are merely headquarters; the great army of field workers must be cantoned about, everywhere. Pennsylvania might easily have for itself sixty live geological societies localized in its county towns and at its mining centers.

J. P. LESLEY.

1008 Clinton street, Philadelphia, May 5, 1883.

Letter of Prof. Frederick Prime, Jr.

Prof. J. P. LESLEY,

State Geologist of Pennsylvania:

DEAR SIR: Herewith I transmit to you a report on the limestone district of Northampton county, together with the northern portion of the Laurentian rocks of the South mountains.

In the survey of this region I was assisted during a portion of each season of 1875, 1876, and 1877, by Messrs. Ellis Clark, Jr., Ellis C. Kent and A. P. Berlin as aids, who have all shown faithfulness in their work. The construction of the map is entirely the work of Mr. Berlin, and this shows the care and faithfulness with which he performed his labor.

I am under obligations to John Fritz, Esq., superintendent of the Bethlehem Iron Company; F. L. Clerc, Esq., of the Lehigh Zinc Company; Michael Fackenthal, Esq., superintendent of the Saucon Iron Company; Joseph Hunt, Esq., assistant superintendent of the Crane Iron Company; Frank Firmstone, Esq., superintendent of the Glendon Iron Company; Prof. W. T. Roepper, of Bethlehem, and others, for valuable aid in the prosecution of the work.

Yours very respectfully,

FREDERICK PRIME, Jr.

907 Walnut street, Philadelphia, 1878.

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Geological colored map of Northampton county.
Geological colored map of Lehigh county.
Topographical map of Limestone belt geologically colored; in 6 sheets.
Topographical map of the Reading and Durham or South Mountain region in 17 sheets.
Index map of the Limestone belt and mountain region from Reading to Easton, geologically colored, on one sheet.
Map of the Boyertown iron ore mines in Berks county.
Map of the Siesholtzville mines "
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THE GEOLOGY OF

NORTHAMPTON COUNTY

AND OF PARTS OF

LEHIGH AND BERKS.

CHAPTER I.

*Introduction.**

NORTHAMPTON COUNTY was laid off from Bucks county in 1752, and extended at that time over what is now Lehigh, Schuylkill, Carbon, Monroe, Pike and all other counties to the north of them as far as the New York State line. In 1772 Northumberland took its north-western parts; in 1796 Wayne its north-eastern part; in 1811 it lost Schuylkill, in 1812 Lehigh, in 1836 Monroe, in 1843 Carbon; and was reduced to its present dimensions of 375 square miles, or 240,000 acres, lying south of the Kittatinny mountain, with a population of 47,904 in 1860, of 61,432 in 1870, and of in 1880.

The Northampton county lines follow for long distances the channel ways of its two principal rivers; its northern boundary being the crest of the Kittatinny mountain, through which the two rivers break.

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*By J. P. Lesley.

The Delaware water gap is at the north-east corner of the county, and *The Lehigh water gap* at the north-west corner; the length of the Kittatinny mountain between the two being in a straight E. N. E. line 27½ miles. The two rivers flow from the gaps S. S. E. in parallel lines, and form the east and west county lines, New Jersey lying east of the Delaware and Lehigh county west of the Lehigh.

The Delaware flows thus S. S. E. 8 miles to Manunka Chunk and there bends and flows (with some irregularities) S. S. W. 15 miles (if measured in a straight line, but 20 miles if measured along its channel) to Easton.

The Lehigh river flows S. S. E. 16 miles (if measured straight, but 18 miles by the water) to Allentown, and then making a right angle bend flows E. N. E. 13 miles into the Delaware at Easton.

Within this area lie all but two of the townships. Lower Saucon and Williams townships extend south of the Lehigh up into and over the first ridges of the Durham hills, a prolongation of the Highland mountains of New Jersey, through which the Delaware cuts a tortuous channel from east on southward six miles (straight, 8 by water) to the south-east county corner of Northampton, the north-east county corner of Bucks.

The Northampton-Bucks county line is nearly straight S. W. along the top of the Durham hills. The south county corner is at the Philadelphia-Bethlehem road, 1½ miles south of Bingen P. O. Thence the county line runs N. W. across the valley of the Saucon, and north to the Lehigh river opposite Bethlehem. All on the west of this is Berks county.

There are 18 townships of Northampton county arranged in the following order on the map:—

Upper Mt. Bethel,
Lehigh, Moore, Bushkill, Plainfield, Washington,
Upper Nazareth, Lower Mt. Bethel,
Allen, East Allen,
Lower Nazareth, Forks,
Palmer,
Hanover, Bethlehem, Easton,
Lower Saucon, Williams.

Easton at the confluence of two great rivers was the scene of the famous treaty with the Five Nations of Indians. The town was laid out in 1773, 75 miles from New York and 60 from Philadelphia (by rail,) and grew to have a population of 10,987 (exclusive of suburbs) in 1870, and of 11,924 in 1880. It is the seat of Lafayette college.

Bethlehem, where the North Penn railway from Philadelphia joins the Lehigh valley railways, was founded by the Moravian missionaries in 1741, as their chief seat of action and learning. It shared in the prosperous local trade inaugurated by the construction of the Lehigh canal navigation (1827), and subsequently by the opening of the Lehigh Valley railroad and afterwards of the L. & Susquehanna railroad in 1840, leased in perpetuo to the N. J. Central in 1871. In 1870 the population of the township was 2230, of the borough 4512, and of the borough of South Bethlehem 3556.

South Bethlehem is the site of Lehigh university; the Bethlehem iron company's mills; extensive zinc and brass works, &c.

Nazareth was chosen for the seat of his school by George Whitfield in 1739, and then sold to his friends the Moravians of Bethlehem, led by Count Zinzendorf, who established there their boys' school, keeping their girls' school in Bethlehem. It has always retained its rural character and had a population of only 949 in 1870. It lies on the great northern turnpike leading over the mountain at the Wind gap.

The principal villages in Northampton county are the following:

1. In Upper Mt. Bethel.

Slateford, at the quarries below the Delaware Water Gap.

Portland, where Jacobus creek enters the Delaware.

Marshfield Station on the railroad and river.

Williamsburg or Mount Bethel Post Office a mile southwest from Portland, on the main road to Easton.

Centerville, three miles southwest of Portland, and on the same road from Portland to Easton.

Johnsonville, in the center of Upper Mount Bethel township, at the junction of the Tots Gap and Fox Gap roads leading into Monroe county.

East Bangor, at the slate quarries, inside the Upper Mount Bethel township line.

2. In Washington.

Bangor, at the slate quarries on Martin's Creek.

Flicksville on Martin's Creek a mile south of Bangor.

Ackermans on the west branch of Martin's Creek, a mile west of Flicksville.

Factoryville on the same, a mile and a half south of Flicksville.

Richmond in the east corner of the township.

3. In Lower Mount Bethel.

Mount Pleasant in the center of the township.

Martin's Creek Post Office, half a mile above the mouth of the creek.

4. In Forks township.

Shimerville at the north edge of the township.

Churchville a mile south-west of Shimerville.

Shernerville on the Delaware two miles above Easton.

Chestnut Hill, a mile north of Easton.

5. In Palmer.

Stockertown, at the north end of the township.

Friedenthal, on the Bushkill half a mile west of Stockertown.

Seipsville, two miles west of Easton.

6. In Plainfield.

Kesler's, two miles north of Shimerville.

Belfast, two miles west of Kesler's.

Point Edward, at the south-west corner of the township on the Bushkill.

Wind Gap Post Office, two miles south of the Wind Gap.

Hellerville, one mile south of the Wind Gap.

Blue Mountain Post Office, two mile east-south-east of the Wind Gap, on the railroad.

Penargil, at the slate quarries, two miles east of the Wind Gap, at the end of the railroad.

7. *In Bushkill.*

Clearfield, a mile north-west of Bushkill Centre.

Jacobsburg, a mile east-south-east of Bushkill Centre, on the Bushkill.

Millgrove, a mile and a half south of Bushkill Centre, on the Bushkill.

Filetown, half a mile east of Millgrove.

Cherry Hill, half a mile south of Millgrove, and half a mile north of Nazareth.

8. *In Upper Nazareth.*

Schoeneck, half a mile north of Nazareth.

Christian Spring, a mile west of Nazareth.

Georgetown, half a mile south of Christian Spring.

New Centerville, three miles west of Nazareth.

9. *In Lower Nazareth.*

Hallo, one mile south-east of Nazareth.

Newburg, two and a half miles south-west of Nazareth.

Hecktown, three miles south-west of Nazareth.

Smoketown, one mile north-west of Newburg.

10. *In Bethlehem.*

Freemansburg, on the Lehigh two miles east of Bethlehem.

Hopesville, on the Lehigh five miles east of Bethlehem.

Butztown, two miles north of Freemansburg.

Wagnertown, two miles north-east of Freemansburg.

Farmersville, three miles north-east of Freemansburg.

Altona, one mile north of Bethlehem.

11. *In Hanover.*

Schoenersville, three miles north-west of Bethlehem.

12. In East Allen.

Jacksonville, in the center.

Weaversville, on the west line and Catasauqua creek.

Bath borough, north-east corner of the Manocacy.

13. In Moore township.

Kleckersville, in the center of the township.

Chapmans', at the quarries two miles north of Bath, on the Manocacy and railroad.

Moorestown, two and a half miles north east of Chapmans.

Point Phillips, three miles north of Chapmans.

Dannersville, two miles west of Chapmans,

Beersville, near the west line and Hokendauqua Creek.

Immanualsville, four miles west by north of Chapmans.

Youngsville, five miles north west of Chapmans.

14. In Lehigh township.

Petersville, south-east corner on the Manocacy.

Newhartsville, on Indian Creek, one and a half miles west of Petersville.

Howersville, on Indian Creek one mile north of Newhartsville.

Rockville, on Indian Creek, east branch, near the line.

Danielsville, one mile south of Little Gap.

Berlinsville, two and a half miles south-east of the Lehigh Water Gap.

Poplar Grove, three miles south-east of the Lehigh Water Gap.

Cherryville, four miles south-east of the Lehigh Water Gap.

Walnutport, two and a half miles south of the Lehigh Water Gap.

Newhartport, three miles south of the Lehigh Water Gap.

Lockport, four miles south of the Lehigh Water Gap.

Treichler's station, on the Lehigh river bend.

15. In Allen.

Kreidlerville, on Hokendauqua Creek.
Seemsville, on the east line.
Bowertown, on the east line.
Siegfried's Bridge, on the Lehigh.
Newport, on the Lehigh.
Laubachsville, at the mouth of Hokendauqua Creek.

16. In Williams.

Raubsville, on the Delaware, below Easton.
Uhlersville, half a mile below Raubsville,
Stout's, in the south-west corner.

17. In Lower Saucon.

Shimersville, at the mouth of the Saucon creek.
Hellertown, three miles south of Shimersville on the North Penn railroad and Saucon creek.
Leithsville, one and a half miles south of Hellertown.
Seidersville, two miles south of South Bethlehem.

LEHIGH COUNTY was laid off from Northampton county in 1812; viz: all that part of the Great Valley west of the Lehigh river as far as the Berks county line; and all the South mountain part from opposite the mouth of the Manocacy south west to the Berks county line. The Kittatinny mountain has always been its northern boundary. Its area measures 364 square miles, or 232,960 acres, with a population of 43,753 in 1860, 56,796 in 1870, and in 1880.

Lehigh county is a nearly rectangular figure, leaning northwest.

Its northern line follows the pretty straight crest of the Kittatinny mountain from the Lehigh water gap W. S. W. 16 miles to the north east corner of Berks county.

The western line, common to Berks, runs perfectly straight S. 50° E. 26 miles; and thence, common to Montgomery,

onward 3 miles,=29 miles in all, to the north west corner of Bucks county.

Its southern line is straight N. 38° E. 6 miles and then straight N. 50° E. 5 miles further to the south corner of Northampton.

Its eastern line follows down the Lehigh from the Water gap to Bethlehem; and then the Northampton lines to the Bucks county line.

There are 14 townships in Lehigh county arranged in the following order on the map:—

Washington,
Heidelburg, N. Whitehall,
Lynn, Lowhill,
Weissenburg, S. Whitehall, Hanover,
U. Macungie, Salsburg,
L. Macungie,
U. Milford, U. Saucon.
L. Milford,

Allentown was laid out in 1751, and grew to be a city of 13,894 inhabitants in 1870, and of 18,063 in 1880; first through the coal traffic on the canal, and then through the iron industry of the neighborhood; its own iron works and those of Catasauqua and Hokendauqua further up the river; the ore being brought in from numerous mines by the East Penn railroad which connects it with Reading; and from New Jersey and the seaboard by the Lehigh and Susquehanna railroads.

The Allentown Iron Works have 5 stacks and the Allentown Rolling Mill 2 stacks just above the town.

The Crane Iron Works have 4 stacks on the east bank of the river, higher up, in Hanover, the only township lying on that side of the Lehigh.

The Thomas Iron Works have 6 stacks at Hokendauqua 4 miles above Allentown.

The Lehigh Valley Iron Works have 2 stacks.

The Coplay Iron Works have 3 stacks adjoining Hochendauqua on the north

These 21 furnaces with their mills and shops make the valley of the Lehigh for several miles above Allentown a

scene of great activity; and have converted what were mere baiting places on the old canal into large and populous villages, such as

Catasauqua on the east bank, at the mouth of Catasauqua creek.

Hokendauqua and *Coplay* on the west bank, opposite the mouth of Hokendauqua creek, and between Coplay creek and river.

In the interior of the county are other furnaces around which former rural villages or iron mine hamlets are growing into similar importance; such as

Emaus, (1 stack,) 5 miles S. S. W. of Allentown, on the East Penn railroad.

Macungie, (1 stack,) 4 miles west of Emaus on the same railroad.

Alburtis, (2 stacks,) 10 miles S. W. of Allentown at the crossing of the East Penn and Catasauqua and Fogelsville railroads, and 7½ miles west of Emaus.

According to the census of 1880, the total amount of *pig iron*, *rolled iron*, *steel and blooms*, made in Lehigh county in 1880, was 324,875 tons; and in Northampton county, 322,882. The iron ore mines of Lehigh county having been all described in previous reports (D, D²) need no further mention here.

The villages and hamlets of the county will now be designated in their respective townships, first along the Lehigh river:—

1. *In Washington.*

Slatington, 2 miles south of the Water Gap at the mouth of Trout creek; at the great slate quarries.—*Kerns* is a suburb on the north side of the creek.—The Lehigh and Berks railroad starts here,

Slatedale, on Trout creek, 2½ miles west of Slatington.

Balliet's furnace, on a north branch of Traut creek near the west township line, 4 miles west of Slatington.

Treichlersville, (not the one at the bend of the Lehigh in Northampton county; which is known on the Lehigh map as *Kuntzford*) 2 miles S. S. W. of Slatington.

2. *In North Whitehall.*

Lawry's station, on the L. V. RR. and river, at the mouth of Fell's creek.

Whitehall, at Siegfried's bridge, on the Lehigh.

Coplay, at the south-east corner, a mile above Hokendauqua on the Lehigh, already mentioned.

Balliotsville, in the center of the township.

Ironton, at the mines, 1 mile south of last, and at the end of the Ironton railroad from Coplay.

Rughsville, on the south township line, 3 miles west of Hokendauqua.

Siegersville, on the south township line and on the Siegersville branch railroad to Orefield.

3. *In South Whitehall.*

Orefield, ½ mile S. of Siegersville; end of railroad.

Guthville, ½ mile S. of Orefield, and on Jordan creek.

Crackersport, 1½ miles S. E. of Guthville.

Iron Bridge, where the Catasauqua and Fogelsville railroad crosses the Jordan, 5 miles S. W. of Hokendauqua.

Scherersville, on the Jordan, 2 miles N. W. of Allentown.

Dorneysville, on the Allentown railroad, 3 miles W. S. W. of Allentown.

4. *In Salsbury.*

Emaus, on the South-west township line, and East Penn railroad, 4½ miles S. W. of Allentown.

5. *In Upper Saucon.*

Friedensville, in the Saucon valley, 5 miles S. E. of Allentown.

Saucon Valley, 2 miles W. S. W. of Friedensville.

Centre Valley, on N. Penn RR., 2 miles S. of Friedensville.

Coopersburg, 1½ miles S. of Centre Valley.

Locust, in south corner of township.

Limeport, where the South Branch Saucon crosses line.

6. Lower Milford.

Chestnut Hill, 1½ miles S. S. W. of Limeport.
Dillingersville, half way of the N. W. township line.

7. Upper Milford.

Vera Cruz, 2 miles south of Emaus.
Zionsville, 2 miles S. W. of Vera Cruz.
Schimesville, 1 mile N. W. of Zionsville.

8. Lower Macungie.

Millerstown, where East Penn RR. crosses Swope creek.
Hensingersville, 2 miles S. W. of Millerstown, and 1 mile S. of RR.
Weilersville, on the Jordan, 3 miles W. of Millerstown.
New Texas, 2 miles N. of Millerstown.
Westcoeville, on Allentown RR., 5½ miles W. of Allentown.

9. Upper Macungie.

Trexlertown, on Allentown RR. at junction of Fogelsville and Catasauqua RR., 8½ miles from Allentown.
Breinigsville, on A. RR., ½ mile W. of Trexlertown.
Kuhnsville, on F. & C. RR., 3 miles N. of Trexlertown.
Fogelsville, 2½ miles N. N. W. of Trexlertown.

10. In Lowhill.

Weidasville, on Jordan creek, in center of township.
Lowhill P. O., on Jordan creek, N. W. corner of township.

11. In Heidelberg.

Pleasant Corners, on Jordan creek, 1 mile from south line.
Germanville, on Jordan creek, 1½ miles above Pleasant Corners. Here the Lehigh & Berks RR. crosses the Jordan.

12. In Lynn.

Tripoli, on L. & B. RR., and Antelawny creek, 1 mile from east township line.

Lynnport, on L. & B. RR., and Antelawny creek, 3 miles W. of Tripoli.

Jacksonville, 1½ miles W. of Lynnport.

Steinsville, on W. line of township, 2½ miles S. E. of county corner on the crest of the mountain.

Lynnsville, head of Kistler's creek, flowing west, and Switzer creek flowing east, 1 mile from south township line.

13. Weissenberg.

Heinemansville, in center of township.

Helfrichsville, in southern corner of township.

Seipsville (another in Northampton co.) 2 miles east of Heinemansville.

14. In Hanover, E. of Lehigh river.

Catasaqua, at the north west corner.

Bridgetown, a suburb of Allentown.

West Bethlehem, a suburb of Bethlehem.

Rittersville, 2 miles west from Bethlehem.

Schoenersville, on the county line, 4 miles north west of Bethlehem.

Rivers and creeks.

1. Of Northampton county.

Saucon creek is the only important stream in Northampton county which flows north. All the rest head near the Kittatinny mountain and flow south either into the Delaware or into the Lehigh; and in doing so they flow out of the slate region into the limestone region; and flow against the geology, for the general dip is northward, *i. e.*, towards the Kittatinny mountain; while at the same time most of the special local rock-dips are southward, *i. e.*, from the mountain towards the rivers. This seeming paradox will be presently explained.

The bend of the Delaware at Belvedere is a significant geological fact. From the Water gap to the Manunka Chunk bend the river cuts square across the edges of the

slate beds; is then deflected S. W. and W. still in the slate; and then swinging round S. W. and S. enters the edge of the limestone 200 yards above Belvedere. Just in front of the town it turns sharply S. W. and flows, in the limestone belt, to within 3 miles of Easton. Here it cuts diagonally through a spur of Scotts mountain, and gets again into limestone at Easton. The natural course of the river from Manunka Chunk would have been straight on S. S. E. across New Jersey by the line of the Warren RR. and New Jersey Central. But Scotts mountain stands in its way and it has to flow westward along the limestone valley to Easton.

The bend of the Lehigh at Allentown is a repetition of the same story in a reversed sense. The river traverses the slate rocks at right angles, and enters the limestone belt above Hokendauqua. But here the limestone belt is broad and the south mountains still far off. The Lehigh therefore keeps straight on to Allentown. Here it has to turn eastward and flow along the foot of the mountains to Easton, keeping in the limestone rocks all the way.

Richmond creek flows 7 miles across the slates and 1½ miles across limestone to its mouth 3 miles below Belvedere.

Martin's creek drains the foot of the Kittatinny mountain, east of the Offset, by two converging branches, and flows southward 9 miles across the slates, and half a mile across the limestone, to its mouth in the bend of the river 7 miles above Easton, and 6 miles below Belvedere.

Muddy creek is 5 miles long and enters the river 1½ miles below Martin's creek.

Bushkill creek drains the foot of the Kittatinny mountain east and west of the Wind gap by two wide spreading branches, and after crossing 7 miles of slate and 5 of limeston, enters the Delaware through a rocky gorge in Easton.

Manokesy river crosses the slate belt from the foot of the mountain in three branches, which unite in the limestone belt; makes a great bend to the east to Hicktown, and then back to the west; and enters the Lehigh river at Bethlehem. Between Easton and Bethlehem, 10 miles, no stream enters the Lehigh from the north; the limestone drainage

being all underground, and in the direction of the strike, parallel to the river.

Catasauqua creek heads in the slate belt near its southern edge and flows south, like the Monokesy, 6 miles across the limestones, and enters the Lehigh river 3½ miles above its Allentown bend. It thus makes a V with the course of the Lehigh across the limestone belt.

Hokendauqua creek, with its spreading tree of branches, drains the Kittatinny mountain slope from Point Phillips to Danielsville (8 miles E. & W.); flows south along a remarkably tortuous channel across the slates; then 2 miles across the limestones, nearly parallel to the Lehigh; and enters the river 3 miles above the Catasauqua creek, 6 miles above the Allentown bend.

Indian creek is the main west branch of the Hokendauqua.

Bertsch creek drains the slate belt at the north-west corner of the county, southward, into the Lehigh at Lockport.

All these streams flow south across both the slate and the limestone belts.

Slateford creek and

Cobus or *Jacobus creek* in the north-east corner of the county, break the rule, and drain eastward into the Delaware; the latter at Dill's ferry 3 miles below the Water gap. But its head waters flow from the foot of the mountain southward to a right angle bend in a prong of the New Jersey limestone which projects into Pennsylvania. Had it not been for this anticlinal prong of limestone Cobus creek would have flowed on south into Richmond creek; and it is possible that it originally did so. But any such former channel was necessarily dammed by the *great moraine*, and the creek now follows the outcropping limestone strata E. N. E. to the river.

Saucon creek drains the various valleys between the South mountains south of the Lehigh, and the united waters issue northward at Bethlehem.

Fry's creek follows a limestone valley between two of the South mountains to the Delaware, 5 miles (in strait line) below Easton.

The mountain belt through which the river cuts from below Easton, southward, to the bend at Kintersville in Bucks county, where it enters the New Red country, consists of parallel anticlinal ridges of Laurentian gneiss, separated by synclinal valleys of limestone. The numerous *bends* of the river are caused by its repeated deflections (to the right) against the northern slopes of these ridges. The deflection of the river is usually at the junction of the underlying gneiss with the overlying limestone.

The Lehigh river behaves in the same way at Treichler's Station, 6 miles below the Lehigh Water gap. Here the river in its course across the slate belt meets upturned sandstone strata intercalated in the mass of the slates; and the resistance of this sandstone to erosion has caused the river to *bend* to the left (East) and even double back upon its course for two miles; then it turns sharply south, breaks through the sandrocks, and passes on across the rest of the slate belt.

The bend at Allentown in like manner is caused by the rising of the Potsdam sandstone formation No. I from beneath the bottom limestones of No. II at the foot of the South Mountain. This Potsdam no doubt once faced the whole slope of the mountain, and covered the summit; for it is found on the southern side of the range both in Pennsylvania and New Jersey. But all that now remains of it is a low outcrop south of the river and along the foot of the mountain in Lehigh county, as described in Reports D, D^2, and in a subsequent chapter of this report.

The Lehigh not only flows from Allentown to Easton against the face of the upturned Potsdam sandstone, but actually in a trough of Potsdam, containing limestone; the only important deflection in its course being its *bend* at Freemansburg, 3 miles below Bethlehem, around the west end of one of the South Mountain ridges.

The Bushkill imitates the Lehigh by bending eastward as soon as it strikes Chestnut Hill, which is the west end of the northernmost of the New Jersey Laurentian highlands.

Hokendauqua creek is deflected at Kreidersville by the southern slate edge of a small outlying limestone basin

(shown on the colored topographical map) along which it flows for some distance.

The deflections of the *Saucon* are of a similar geological nature; the main stream and its branches flowing sometimes along the strike of the limestones, and sometimes cutting through the gneiss.

The *swamps* of the northeast corner of Northampton are caused by Northern Drift as will be explained in a following chapter.

The *sinkholes* of the limestone belt are merely surface entrances to an underground drainage system of communicating caverns underlying the whole of this part of the county.

The most remarkable of them is one four miles north of Easton, and ¾ mile west of Bushkill, where a road from the east meets the road leading due north to Stockertown.

If the reader will mark the 350′ A. T. contour line with a red or blue pencil he will see its form and character. Two shallow vales descend from the north and south-west and deepen into a valley descending east to the sink hole at the road. This valley, instead of opening into the valley of the Bushkill ends in two vales ascending northward and southward parallel to the Bushkill. A barrier of limestone like an artificial dam stops the valley short, and whatever rain water falls must sink at the road and pass under this barrier to reach the Bushkill. That is probably the direction of the underground drainage; for the reader will notice five arrows on the map at the sink hole, showing that the limestone rocks dip *north* 38°, 47°, 48°, 64° increasing to 79° at the sink hole. There is probably a little fault or broken anticlinal here, which has caused the sink; and which must govern the direction of the underground drainage.

The Bushkill bed is here say 275′ A. T. The top of the barrier reads something over 350′ A. T. The bottom of the sink hole hollow is say 295′ A. T., that is, 20 feet higher than the bed of the Bushkill; and 55 feet lower than the top of the barrier,

It is very evident that this little double-headed valley once delivered its rain water (for it has no constant stream) over the barrier into the Bushkill; and that it has deepened its bed since the sink hole was opened *at least* 35 feet along a mile of its course and *at least* 55 feet at the sink hole; how much more is uncertain. In the meantime however, the Bushkill must have deepened its bed at least as much, and no doubt much more, because it is a large, rapid and sometimes a furious little river. If so, its bed ought once to have been *higher*, not *lower*, than that of the little valley. But again, if so, it becomes highly probable that the two heads of the little valley are really on the line of the ancient Bushkill, which then must have kept straight south (from its present bend ½ mile west of Stockertown) through the little valley to the west end of the Chestnut hill west of Seip's. Since then it has cut its wide curve, between the north and south cusps of which the supposed old channel makes a straight line. Still later in time the Bushkill changed its course again and cut its present gap through Chestnut hill.

Another remarkable sink hole lies about a mile east of Catasauqua. The road from Howertown south to Bethlehem descends from a knoll (375′ A. T.) 70′ in a quarter of a mile, into a sort of ditch half a mile long, the bottom of which is at 305′ A. T. Catasauqua creek near its mouth, a mile off, is 270′ A. T. The ditch heads up suddenly in that direction (S. 53½° W.) against a barrier of limestone 355′ A. T. In the other direction (N. 53½° E.) it runs on a mile and half, then bends to due north, runs a mile, and heads at the remarkable pimple hill of limestone mentioned in connection with the slate border. It is evidently the abandoned valley of an ancient stream, which, flowing at a much higher level, entered the Catasauqua just above its junction with the Lehigh. The arrows about it all point *south* (not S. 36½ E. as one might expect) and show dips of 19°, 29°, 37°, 33°, 32°, 20°, 37°. An extensive group of arrows, a mile up the valley, where the Shoenersville road

crosses it, all point *south* (*i. e.* diagonally across it) and the dip varies from 18° to 26°.

In this case the evidence of valley erosion is of the plainest and most conclusive character; for the slant of the valley south-westward is according to the universal rule of a stream undercutting the basset edges of strata presented towards it by a gentle dip. There is no appearance of an anticlinal, fault, or disturbance of any kind in the immediate neighborhood of the sink hole; but the *southward* dips indicate both a synclinal to the south and an anticlinal to the north. Consequently *north-pointing* arrows are seen on the Catasauqua a mile north of the sink hole; and on the Lehigh a mile and a half north of the mouth of the Catasauqua; and up the sink hole valley ⅝ mile north of Shoenersville.

By connecting these groups of north dips, we get the axis of a great anticlinal on a nearly due east and west line, and see clearly that the little valley bends from south to southwest just where it cuts the axis of the anticlinal and begins to meet the upturned edges of the south-dipping rocks.

These sink holes are here described thus minutely to draw attention to the amount of erosion the limestone country has undergone; the gradual lowering of its surface; the innumerable changes in their course which all its flowing waters have made from time to time; the capital rôle which the underground drainage has played in the drama; the influence which the broken anticlinals, faults and other local complications of the rock strata have exerted over both the underground and surface drainage; and lastly (as will appear more fully further on) the important bearing which all this has upon our views of the age of the Easton and Bethlehem gravels; the time of ice; and the reasonable theory that the palæozoic formations once covered the South Mountains.

2. *Streams in Lehigh County.*

The *drainage* of five sixths of Lehigh county is directed to Allentown and passes through the gorge at the sharp bend of the Lehigh already described.

The *drainage* of a northern belt of the slate region about 4 miles wide lying along the foot of the Allegheny mountain is peculiar. Its eastern third drains east, by the two branches of *Trout creek*, into the Lehigh at Slatington; its western third drains west, by the two branches of *Antelawny creek*, through Berks county, into the Schuylkill; and its middle third drains south by the numerous head runs of the *Jordan* into the Lehigh at Allentown.

The southern and central part of the slate regions, crossed by the valley of the Jordan, has its rainfall gathered in by side creeks from the right and left. Two small streams drain its eastern end eastward into the Lehigh above Hokendauqua; and its western border drains westward into Berks county.

The limestone region is scarcely drained by the Jordan, which merely meanders through it eastward to Allentown. Its eastern portion is drained eastward by *Coplay creek* in to Lehigh at Hokendauqua; all its central, western and southern parts are traversed by the *Little Lehigh*, which has its head-waters in Berks county, and receives its southern affluents from the ravines between the South mountains.

Such is a general outline of the drainage of the county. But certain features require special notice.

1. The *Kittatinny mountain* is an unbroken barrier (west of the Lehigh Water gap) through which no stream flows. A steep south slope of slate, crowned with a line of broken rock and occasional crags of Oneida conglomerate, carries its crest along at an even height of about 1500′ A. T. in a straight line, S. 15° W. for 4½ miles to the first road which leads over it from Balliot's furnace. Here is a deflection to S. 45° W. for 5 miles. Thence its course is straight S. 30° W. for 5 miles. Another deflection to S. 45° W. for 2 miles. Thence straight S. 25° W. for 5 miles to the Berks county corner; and so onward. *

Bake-oven Knob, 7 miles west of the Water Gap, is the only prominence which breaks the apparent dead horizon-

* These courses and distances are not accurately correct, but will suffice to illustrate the general straightness of this mountain wall.

tality of the crest line. Although it is a notable object in the landscape, and affords a magnificent view of Carbon and Lehigh counties, it only rises about 100 feet above the general level of the crest or to 1,560′ A. T.*

Immediately under its precipices of rock a *half bowl* has been scooped out of the southern slope of the mountain, which, if the erosion had not been stopped, would have located the Lehigh Water Gap here instead of seven miles further east, where it now is. This *half gap* is the more peculiar because it has scarcely made a notch in the crest of the mountain, and has no adequate representative on the north face of the mountain. Its origin is still a mystery. The eastern of the two head-brooks of the Jordan, heads just in front of it; but so also does the northern branch of Trout creek.

The Bear rock, 2 miles west of the Bake-oven, is another precipice of Oneida rocks, at the crest of the mountain; 1500′ A. T. Here Schuylkill and Carbon counties corner.

Two slight depressions of the crest line occur where small mountain farms have been cultivated, and roads cross into Schuylkill county: one at the Widow Snyders 3½ miles, the other at Geo. Bremer's 5½ miles west of the Bear Rock; the latter at the Berks county corner. The road which crosses the mountain half a mile west of the Bake-oven goes over the crest. But the road that crosses 2½ miles east of the Bake-oven finds the crest slightly lowered.

A multitude of small brooks descend the slope of the mountain, most of which feed the northern branches of *Trout creek* eastward, and *Antelawny* creek westward; only a few combine to start the Jordan in its southward course.

2. The drainage of the northern belt of slate region cannot be understood without reference to a line of high hills, which traverse the slate region on an almost due east and west course represented by the Heidelberg-Lowhill township line.

*** The crest overlooking the Water Gap from the west is given on the county map as 1450′ A. T.**

Shochary ridge is a continuation of this line westward through Lynn township; its height is 800′ A. T., but it culminates in the *Donat-pig* or *Spitz-berg*, on the Berks county line, 1,100′ A. T., where the *Antelawny creek* makes a deep gap through it. In Berks county it forms a wide high ground and finally rises (to the usual height of the Kittatinny mountain) as the great spur which runs out east from the Schuylkill Water Gap at Port Clinton.

The Jordan breaks through the *Shochary ridge* ½ mile above Lowville, where it is settling down to the general level of the slate hill region; but its influence on the drainage of of the county is no longer apparent. In fact this synclinal slate ridge as a distinct topographical feature may be said to stop at the Jordan; for the waters between the Jordan and the Lehigh pay no regard to it.

No such ridge occurs in other parts of the slate region, but a third feature of the topography must be mentioned which is of an analogons kind and influences the details of the drainage; viz:

3. *Slate ridges* in the limestone region. These spur out eastward from the main area of slate, and subdivide its north-western border into coves.

These *slate ridges* and *limestone coves* distinguish Lehigh from Northampton county. They are marked by the colors on the four sheet map of Lehigh county published with Report D² and described in the text of that report: 1. The very small cove at Ironton; 2. the large cove in which Orefield, Rughsville and Mechanicsville are situated, occupying the country on both sides of the N. and S. Whitehall township line; and 3. the smaller cove of Fogelsville.

Three spurs of slate separate these coves from one another and from the southern edge of the slate:—1. the short spur of slate south of Ironton; 2. the slate ridge called *Huckleberry ridge*, 4 miles long, lying due E. & W. in S. Whitehall township, north of Crackersport and Kuhnsville; and 3. the slate spur at the head of Breinig's run and around which *Spring creek* bends 2 miles N. W. of Trexlertown. This spur has on its south side a knob called *Haas hill.*

It is easy to see the effect of these synclinal relics of the slate formation, left in the midst of the limestone region, by noticing how Huckleberry ridge has stopped the southward course of the Jordan and sent it meandering eastward to Allentown.

Each spur, as it joins the main body westward, widens by just so much the slate region, transferring its southern border southward, as the colored county map shows; so that, while the whole slate belt is only 8 miles wide on the Lehigh river, it is 12½ miles wide at the Berks county line. The whole of the four townships of Heidelberg, Lynn, Lowhill and Weissenberg lie entirely within the region of the slate hills; the slate border running just outside the southern line of Weissenberg.

The slate township Weissenberg is drained mostly eastward by Switzer run and Lyon creek and Haasen creek into the Jordan; but its southern edge drains southward and westward by Schaeffer's run; and its northwestern part by Maxatawny head waters southwestward into the Schuylkill.

3. The three geological regions.

A. Northampton county.

Northampton county is divided into three parallel belts of country, or regions:—1. The northern slate belt about 7 miles wide; 2. A middle limestone belt about 7 miles wide; and 3. A southern granite (properly syenite) or gneiss belt, about 5 miles wide, within the county limits, but about 7 miles wide including what of it lies in Bucks county.

The northern and middle belts together occupy the whole width of the Great or Kittatinny Valley, between the North or Kittatinny mountain and the South Mountains or Durham and Reading hills. These last form the third or southern, syenite, mountain belt.

The Kittatinny Mountain.

The Kittatinny mountain, which forms the northern edge of the northern division or slate belt, is the first of the Appalachian mountains which the traveler from south-east-

ern into middle Pennsylvania encounters after crossing the Great Valley. *Kittatinny* is supposed to be its name in the language of the Lenni Lenape or Delaware river indians.* The early settlers of the Great Valley on the Lehigh, Swatara and Yellow Breeches waters called it the *North* mountain, because it bounded their horizon on the north; and also the *Blue* mountain because of its bluish tint when seen from the southern side of the Great Valley. These are its common names. But the hunters who ascended the Lehigh, Schuylkill, Swatara and Susquehanna rivers found other similar mountains behind it, and numbered them accordingly; calling theBlue mountain the *First* mountain, and the mountain back of it *Second* mountain. The term First mountain never came into use, but the *Second mountain* at Mauch Chunk, Pottsville and Harrisburg has retained its name and has never been called by any other. The *Third* mountain, ending east of the Susquehanna river, is also known by that appellation in Dauphin county, but becomes *Sharp mountain* in Schuylkill and Carbon counties, and its eastern end is Mt. Pisgah on the Lehigh. The *Fourth* mountain on the Susquehanna became *Peter's mountain.* A corresponding mountain on the Lehigh, but not the same, is called the Nesquehoning mountain.

The Kittatinny mountain is a ridge of sandrocks which slope from 30° to 60° northward; its crest a nearly horizontal line, everywhere about the same height (1500 to 1600 feet above the sea); its brow, overlooking the valley on the south, an unbroken line of Oneida sandstone cliffs, about a hundred feet high, below which is a continuous regular steep slope of Hudson river slate, the surface of which is covered with fragments from the cliffs above. The backside of the mountain in Carbon and Monroe counties is a gentler but still pretty steep slope of outcropping Medina sandstones and shales, down to the still higher Clinton red shales in the bottom of the narrow valley of the Aquanchicola and Cherry creeks.

The structure of the mountain.—All the formations in

* The Great Valley is called the Kittatinny Valley in the reports of the First Geological Survey, and the mountain may have been named after the valley.

the mountain dip one way, northwards, and therefore overlie the Hudson river slate formation of Northampton county.

This structure is shown in the Delaware and Lehigh water gaps, maps and sections of which on a large scale and in great detail are published in the Report on Pike and Monroe (G⁶, 1882,) to which the reader is referred.*

The general straight course of the Kittatinny mountain upon the map is an evidence that the dip of its rocks is everywhere nearly alike; and what irregularities are noticeable in the course of the county line, which has been located along its narrow and rocky crest, are partly due to some slight local increase or diminution in the angle of the dip, and partly to the fact that sometimes one and sometimes another of its great sandrocks forms the crest.

But there is one place where the north dip rises again as a south dip and then rolls over again to a north dip in the body of the mountain. This *anticlinal* roll comes from New Jersey, where it elevates a belt of limestone to the surface, throwing the overlying slates to the north and south with opposite dips. As the roll dies down westward the limestone belt comes to a point and the slates (dipping N. and S.) close over it. The axis of the anticlinal passes on westward up the little valley of Offset creek, at the head of which (seven miles west of the river) the sandstones of the mountain close over the slates.

Offset mountain is merely a basin of the sandrocks left in the synclinal trough south of the anticlinal axis; and the offset in the county line east of the Wind gap was made by the land surveyors in their effort to keep upon the crest of the mountain, by running across from the sandstone outcrop south of the roll to the outcrop of the same sandstone north of the roll.

Similar *hooks* in the North mountain occur in Schuylkill, Lebanon, Dauphin, Cumberland and Franklin counties; and are all made alike; only that those west of the Susquehanna point west. To explain this difference is not essential to the purpose of this report. It is enough here to point out the connection between the Offset mountain at the

* See section (page plate) in Mr. Chance's report further on.

Cove behind it with the changes of dip in the slate rocks observable along the Delaware below the Water gap; and also that the slight changes in the course of the mountain as it approaches the Lehigh river are connected with rolls in the slates north of Rockville, Lehigh township, and with rolls in Rocky ridge behind the mountain in Carbon county.

There is a little offset also produced by a small anticlinal, midway between Tot's and Fox's gaps, *i. e.*, 3 miles west of the Delaware Water gap.

There are at least five places along the crest of the Kittatinny mountain where it is notched, viz:—

Tot's gap, 2½ miles west of the Water gap.

Fox's gap, one mile west of Tot's gap.

Wind gap, 11 miles (straight) west of the Delaware Water gap.

——— gap, six miles west of the Wind gap.

Little gap, four miles east of the Lehigh gap.

The *Wind gap* is a curious notch in the mountain, about 500 feet deep, at a point 11 miles from the Delaware water gap and 16½ miles from the Lehigh water gap. The earliest direct road from the Moravian settlements at Bethlehem and Nazareth northward into the wilderness toward the great lakes and Canada, followed a more ancient Indian war trail across the mountain through this gap; and this road became afterwards the North and South turnpike, which forks in Monroe county at Fennersville. A railroad line has been located through it, and the highest R.R. grade level in the gap is 978′ A. T., the crest of the mountain east and west of it being about 1500′ A. T.

The southern approach to the Wind gap is up a gently sloping plain of loose rock and sand which has the appearance of a fan-shaped delta deposit, and seems to suggest that the ocean once stood as high as the floor of the gap covering all Pennsylvania and New Jersey up to the mountain; and that a violent stream of water issued from the gap and spread its coarse deposits out in front of it. It is remarkable that the largest stream of Northampton county, the Bushkill, heads at the Wind gap.

But if any such submergence of the continent took place

it must have been of short duration; and the flow of water through the Wind gap, however violent it may have been, did not last long enough to cut through the mountain to its base, so as to establish a permanent water way. We know of only one age in which such an event could have occurred, and that was the age of ice, just before the appearance of mankind and the present races of animals. This however may suffice to explain the Wind gap. It is certain that America was covered with moving ice as far south as the great moraine, or ridge of loose rocks and sand, on which the village of Portland stands, in Upper Mt. Bethel township, and which has been traced across New Jersey, eastward, and across Monroe county northward and westward into Carbon county, and so on north-westward by Birwick, Ralston and Olean to Salamanca in western New York, and then down past Franklin and New Castle to the Ohio river.*

There is however no direct evidence that the front of the ice which made the great moraine reached to the Wind gap; although it covered the mountain east of the offset, and stopped up the Delaware water gap. But the moraine encircles lake Poponoming, which is only 3 miles north of the gap. In the absence of any barrier across the Aquanchicola valley to the west it seems impossible that the glacial waters could have been so jammed back as to flow through the Wind gap; and as we cannot prove that the Wind gap is not as old as the Water gaps its connection with the neighboring glacial phenomena must remain yet for a time in doubt, and the real cause of its existence unknown. It is a unique and exceedingly interesting fact in the topography of Pennsylvania.

The *Kittatinny mountain* in its course along the north of Lehigh county has already been sufficiently described. It resembles in all respect that part of the mountain east of the Lehigh river, except in the absence of anticlinal hooks.

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*See Report G⁶ on Pike and Monroe; and Report Z on the Terminal Moraine; also the geological reports of New Jersey.

I. The northern or slate region.

The slate belt of Northampton county stretches from the Delaware to the Lehigh for seven miles south of the mountain. It is region of low flat-topped hills, trenched by a multitude of small valleys, and when looked down upon from the mountain, appears like a great plain, which it really is. Its southern border, a nearly straight line from Belvedere to Hokendauqua, is a sort of low wall overlooking the lower and flatter limestone plain to the south of it; and out of this border wall break the various streams already enumerated.

The slate hills along the border only are contoured on the geological six sheet map accompanying this report; and it will be noticed that their summits seldom reach 700′ above tide; most of them range from 600′ to 700′ A. T.

This may be taken as the general elevation of the whole Slate belt up to the foot of the mountain; and therefore the Wind gap has been cut down to within 250′ or 300′ of the plain; while the crest of the mountain runs from 700′ to 800′ above the plain.

The streams which traverse the plain have cut narrow channels in it about 200 feet deep; and the side slopes of these channels are commonly steep and rough, sharp ribs of slate rock sometimes standing out upon them, showing dips at all angles to the horizon. But such exposures are rare; the rule is that the cross cleavage of the slate rocks has permitted them to be weathered into fine pieces, which smooth off the slopes, and at the same time covers the upland with a thick layer of clay soil. This has been increased by the frequent close plication of the rocks into numerous narrow rolls and troughs, running parallel and close together, and sometimes overturned and pressed flat. It is impossible therefore to make out much of the structure of the country; for all that is seen of the rocks is along three or four railroads, and at the slate quarries. The larger synclinal troughs are marked, however, by rounded ridges which run along the belt, sometimes separated from each other and cut through transversely by narrow ravines.

Railroad levels along the Manocacy from Chapmansville

to Bethlehem will serve to show the depth of the valley and the rate of its fall.

Lehigh and Lackawanna railroad.

Windgap, turnpike summit (above tide,)	978′
Chapmansville, 6 miles south of mountain crest,	576′
Bath, 3 miles below Chapmansville,	423′
Clyde, 2 miles below Bath,	362′
Steuben, 2 miles below Clyde,	333′
Brodhead, 2 miles below Steuben,	313′
Reiter, 1 mile below Brodhead,	299′
Shimer's, 1 mile below Reiter,	289′
Peter's Mills,	255′
Bethlehem junction, 4 miles below Shimer's,	240′

At Bath the Manocacy breaks out of the slate hills on the limestone plain, and the map shows the hill tops at Bath to be nearly 700 feet above tide and the water bed of the Manocacy a little over 400 feet above tide—depth of Manocacy valley at Bath 300 feet.

The Delaware and Lehigh rivers cut deeper into the slate plain, as the following tables will show.

At the Delaware water gap.

Kittatinny Mt. crest, east of gap,*	1587′
Kittatinny Mt. crest, west of gap,*	1480′
Hill-tops of slate west side of river,*	640′
Delaware water gap R. R. station,† grade,	319′
Low water at Indian ladder in the gap,§	291′ 8″
Portland R. R. station, grade,†	291′
Delaware bridge R. R, station,† grade,	293′
Newton and Belvedere R. R. junction, grade,‡	275′
Manunka Chunk R. R. station, grade,**	323′
Manunka Chunk river water level,††	265′
Belvedere R. R. station, grade,‡	286′
Belvedere R. R. station, grade,**	271′
Belvedere, river water level,††	235′
Philipsburg, (opposite Easton,) river water level,††	160′

The slate hills along the Delaware are therefore about 400′ high above the river, but become 600 feet at the foot

* From Mr. H. M. Chance's contoured map in G⁶.

† Delaware, Lackawanna and Western R. R. Table 90, N.

§ S. P. Schemerhorn, quoted by I. C. White in G⁶, p. xxiii.

‡ Table 89, Report N, 1878.

** Philadelphia and Trenton (Belvedere and Delaware) R. R. Table 83, N.

†† Table 84, N.

of the mountain, and the top layers of the slate formation crop out under the Oneida cliffs near the top of the mountain at an elevation of 1180 A. T.

At the Lehigh water gap.

Kittatinny Mt. crest east of the gap,*		1505′
" " west of the gap,* (highest, 1525′,)		1385′
Slate hill east of the river,* (knob,)		665′
" west of the river,* (gradual slope,)		——
Water level of river,*		366′
Lehigh gap	station, grade,†	389
Slatington	"	365.7
Laury's	"	329.2
Whitehall	"	301.1
Coplay	"	296
Hokendauqua	"	294.9
Catasauqua	"	282.5
Allentown	"	254
East Penn R.R. junction	"	258.8
North Penn R.R. junction	"	237
Bethlehem	"	235.3
Freemansburg	"	225.9
Redington	"	211.5
Easton	"	210.5
Philipsburg	"	220
Water in the river at Easton,		160

Lehigh and Susquehanna R.R.

Lehigh gap	station, grade,	392.73
Walnut Port	"	371.43
Lockport	"	356.42
Treichler's	"	343.95
Siegfried's bridge	"	315.03
Laubach's	"	303.82
Upper Catasauqua	"	283.53
Lower "	"	271.02
Allentown	"	257.23
Bethlehem junction	"	239.35
Bethlehem "	"	235.54
Freemansburg	"	221.73
Hopes	"	219.51
Glendon	"	215.06
Easton	"	215.1
Phillipsburg	"	217.4

Railway grade in the Lehigh gap is 80′ higher than railway grade in the Delaware gap, (389′—319=80′.) But the

* H. M. Chance's map, in G⁶.

† Table 74.

deeper cut of the greater river is what might be expected, setting aside any effect due to the northern ice passing over the gap of the Delaware and not reaching that of the Lehigh.

The southern border of the slate belt.

The following measurements show how the border of slate hills overtops and looks down upon the the limestone plain.

The slate hill-top southwest of Kreidersville and between Hokendauqua creek and the Lehigh, is 560′ A. T. That over which road from Kreidersville goes southeast to Howertown is 590′ at the road, 630′ a furlong east of the road, and 660′ at Seemsville.

The Hokendauqua flows between them at 330′ A. T.

The nose 1¼ miles on the road south from Seemsville is 565′ A. T.

The road east from Seemsville crosses a nose 620′, and another 600′, and then the ravine of Catasauqua creek (1 m. from Seemsville) at 345′ A. T.

The round-topped hill just south of this is 645′ A. T., and the hill still further south, just on the edge of the limestone, 555′.

The high knob 2¼ miles east of Seemsville and just 1 mile north of Jacksonville rises to 730′, the limestone being only 460′ at the cross roads in Jacksonville, but rising to 520′ on the slope of the slate hill. (One mile S. W. of Jacksonville is a curious little knob of limestone like a pimple on the plain, its top 440′. The arrows show dips in all directions from it.)

The knob ¾ mile west of Bath is 680′ A. T. half surrounded by limestone at 430′. (Here the very steep hill slopes show how the slate formation lies like a cake upon the limestone.) The Manocacy creek at Bath bridge is 420′, and the limestone runs up north into the slate region.

The hill top 1½ miles east of Bath is 610′, and the edge of the limestone on its short south slope comes up to 530′.

The next slate hill east is only 560′ and the next 560′, with still lower slate noses approaching Nazareth ; east of

which the contour lines were confined entirely to the limestone for economical reasons.

This suffices to show that the slate hill-tops along the border overtop the limestone plain by about 200′. But the border line, although straight on a map of very small scale, is really very much notched on a map of very large scale, as we should expect it to be, seeing that the slate formation lies practically horizontal upon the limestone formation, although both of them are excessively crumpled into minute local folds.

In Lehigh county the border hill-tops of slate show about the same relation to the limestone coves and plain, in respect of altitude, as in Northampton county. Thus:

Back of Whitehall (Siegfried's bridge) rises an almost isolated slate hill to 610′.

Two miles west of Whitehall is a line of slate knobs, isolated by the brook that heads up at Treichlersville, which measure respectively (going west) 520′, 650′, 640′, 610′, 620′, 640′ A. T. The limestone comes up on their south slopes to a maximum of 550′; but the plain is about 450° A. T.

At Ballietsville the hill rises west to 680′.

One mile west of Ironton the road goes over the hill-top at 630′.

At Schnecksville, in the slate region, a mile back from the limestone, are summits of 680′ and 690′, 720′, and 640′.

A mile west of Siegersville the knob on the north bank of the Jordan is 590′; that on the south, 640′; while the edge of the limestone in the cove at their east foot is cut down by the Jordan to 340′; but rises northward past Siegersville to its edge at 600′. In the center of the great cove the highest limestone hill east of Siegersville (1 mile) is only 490′.

Huckelberry ridge has a long straight narrow horizontal top of slate a mile long 580′ A. T. At Sneidersville it gets to an elevation of 650′; and the hill top 1 mile west of Sneidersville is also 650′.

The third slate spur, 2 miles N. W. of Trexlertown, has

its top at 640′ A. T.; the edge of the limestone in the cove north of it being at 550, and south of it at 520′; while the limestone floor of the cove is only about 450′; and the little limestone swells around Breinigsville 420′ and 430′.

Two miles W. N. W. of Breinigsville the isolated slate summit is 610′; the limestone in the ravine to the north, which cuts it off from the main body of the slate, is 520′. And so on over into Berks county.

The nonconformity of the slate formation upon the limestone formation is suggested *topographically* at many points along the border which has just been described; but there is no entirely satisfactory evidence of nonconformability between the two formations, or anything to show positively that the limestones were first crumpled, must less eroded, and then the slates deposited upon them.

A nonconformity of the Oneida conglomerate, No. IV, upon the top of the Hudson river slates, No. III, has frequently been asserted. In Pennsylvania they appear to be quite conformable; no erosion of the uppermost slates of III previous to the deposit of the conglomerates and sandstones of IV having been noticed.

At the Rondout quarries in New York the Helderberg limestones seem to lie upon the upturned edges of the Hudson river slate. At Catskill village they appear to lie directly but conformably upon the slate.

Mr. Davis in his recent beautiful memoir (quoted in G[6]) states in his text and shows in his sections an apparently perfect conformability of the *Lower Helderberg* limestones (No. VI) upon *Hudson river* sandstones and slates (No. III) in the vale of the Cattskill, a mile or two back from the Hudson river; with an apparent total absence of the *Clinton* (V), and the *Medina and Oneida* (IV) which usually intervene.

Although the district of country in which these phenom-

ena present themselves is small, yet, out of these local phenomena an hypothesis has been framed and made to apply to a thousand miles of the continent, viz: that the Hudson river age closed not merely with a disturbance of the relations of land to sea, resulting in the shifting of coasts and the deposit of gravels and sands, (which might be easily admitted,) but with huge elevations and upturnings of the sea-bed, extensive erosion, and the deposit of horizontal upon vertical strata.

To this I object: 1. the almost universal conformability of the *Oneida* upon *Hudson river* formation; 2. the absence of *pre-oneida* plications; 3. the impossibility of obtaining the principal materials of the *Oneida* conglomerate, out of any known *Hudson river* strata; 4. the fact that *Oneida* deposits still remain far south of the *Hudson river* belts (as at Greenwood lake in New Jersey); 5. and above all, the fact that at the Schuylkill Water Gap, where the *Oneida* rests at right angles on the apparently eroded edges of *Hudson river* slate, there is in reality a snapped anticlinal and downthrow of the slates, and no unconformability at all.

Mr. Davis shows the *Lower Helderberg conformably overlying Hudson river "sandstones," in a synclinal.*

At first glance this would seem to settle the question of land elevation and subsequent subsidence; and he therefore speaks of *a long interval of time* (Oneida, Medina and Clinton ages) during which no deposits took place.

But a moment's consideration will serve to show the uncertainty of this kind of evidence. For, during all these ages it no doubt rained as often as it rains now; and if so, all land surfaces must have suffered erosion; and yet the slates in his Catskill section are not eroded; they could not therefore have been rained on; *i. e.*, they could not have been above water.

The alternative is to imagine *a stoppage of deposit without elevation of sea bottom.* This is not impossible, but very improbable. For, the Oneida was heavily deposited a few miles west of Newburgh, and from there on for hundreds of miles westward and south-westward.

An easier hypothesis would be to consider the "Hudson river sandstones" which lie beneath the limestones. to be a finer part of the same deposit as the Oneida and Medina conglomerates and sandstones elsewhere.

But there is another alternative: to consider the close proximity of vertical and overturned strata between the quarry and the banks of the Hudson. The crumpling which Mr. Davis so eloquently describes and so artistically portrays has been produced by the sliding down upon itself and mashing together of the still moist formations on the western slope of the Hudson river uplift. Precisely similar crumplings characterize the same limestones all along the north foot of the *Medina-Oneida* mountain range through New York, New Jersey and Pennsylvania. And it is in front of these crumplings at the Delaware, Lehigh and Schuylkill water gaps that the great faults occur which plunge the edges of the slates underneath the upturned bottom of the conglomerate.

It should be kept in mind that our massive formations (XII, X, IV) act independently of the softer formations between them, preserving their own larger plications intact and for themselves, and compelling subjacent and superjacent formations of inferior tenacity and greater ductility to conform to limited spaces by crumpling and sliding. It is quite possible that the faulted edges of the missing rocks may lie deeply buried. At all events, such is not so violent an hypothesis as that the Hudson river slates remained two or three geological ages out of water without suffering the least erosion.

Non-conformity of IV upon III has been argued from the presence of pieces of slate in IV. But there are also distinct bands of intercalated slate between the sandstones. Even supposing fragments of foreign slate, they could not come from neighboring Hudson river outcrops. For, if the Oneida was deposited over the whole region of Northern New Jersey as far south as Greenwood lake, how could any shore produced by an upheaval at the close of the Hudson River age, be near enough to furnish such materials as those of which the Oneida is composed; and how

could "pieces of Hudson river slate" possibly get into the Oneida deposit?

But the most complete evidence that there was no change in the relations of land to water at the top of the slate formation No. III, and before the deposit of the great sand-rocks of No. IV, comes from the shape of the Kittatinny mountain along its whole line from the Delaware water gap, past the Lehigh water gap, to the Berks county corner, and far beyond. Any erosion of the slate formation previous to the deposit of the Oneida sandstone beds would have made the outcrop of the latter very irregular. It is, on the contrary, remarkably regular; and the synclinal sandstone crest in the *Offset* lies quietly in a synclinal of slate; all the rocks dipping in conformity. Any slight difference in angle recorded in the water gaps between the sandstone beds above and the slate beds on which they rest must be due either to imperfect instrumentation; or to the concealment of the actual plane of contact; or to the inevitable slip of the upper rigid mass on the lower flexible mass in the process of uplifting the whole 30° or 40° from the horizontal. When this uplifting reached 90° at the Schuylkill water gap, a great fracture took place, and the whole sandstone mass shot upright into the air, grinding the edges of the slate mass, which remained nearly horizontal, to a smooth plane.

The same sort of movement is seen to have taken place at the Lehigh water gap, and no doubt occurred at many other places along the contact. (See Mr. Chance's sections further on.)

Along the whole range of mountain in Northampton and Lehigh counties, the upper limit of the slates rises to the top of the long slope, to within about 200 feet of the actual crest of the mountain, where the cliffs of Oneida commence. Downwards the mountain slope dies away in the slate plain, chiseled by a thousand brooks which collect the rain water and continue the operation of lowering gradually the general level of the slate belt.

The character of the slate belt will be further illustrated in Mr. Sander's special report, Chapter II of this volume.

II. The middle or limestone region.

The *limestone plain* of Northampton county is about 7 miles wide, and elevated, as the contours on the Six sheet map show, about 400 feet above tide ; its hill tops sometimes reach 450′.

This plain is intersected in every direction by gently sloping vales, mostly destitute of running water ; while sink holes show that a general system of underground caverns carries away the rain water to the beds of the two great rivers which enclose it. This would have been the case even if the limestone strata had remained from the beginning undisturbed and nearly horizontal; but the formation of innumerable subterranean caverns has been greatly facilitated by the universal crumpling and folding to which the limestone deposits were subjected in remote times, probably at the close of the carboniferous age, when the continent was elevated, and the great anticlinals and synclinals of the Appalacian mountain country were produced.

The folds in the limestone strata are like those shown by the sections as affecting the whole Slate belt, are due to the same general cause, and are as numerous and as sharp. They are well exhibited in the quarried cliffs along the Lehigh river, pictures of which were published in a previous report, D^2 pp. 52, 54, 56, 58, where the limestone beds are shown pressed up into a vertical attitude, and pushed over northwards into closely pressed down folds.* This action has broken the strata, permitting the rain water easy access to all the more soluble layers, to a depth limited only by the lowest drainage level of the district, namely, the bed of the Delaware river below Easton, 160′ A. T. Most of the caverns therefore, must be about 200 feet beneath the surface; and many of them may descend to much greater depths in the deeper folds ; because the excavation of limestone caves is not so much a mechanical as a chemical process, and may be carried on by a syphon movement of nearly still waters, holding free carbonic acid, far below the hydraulic plane of mere mechanical drainage.

*A very poor picture of an overturned and compressed fold in the slates near Foglesville, is given on page 47, Report D.

This is an important part of the *theory of erosion*, which has not received that attention from geologists which it deserves. There are no caves in the slate belt, because there is no such chemical erosion. The surface of the slate belt has been lowered gradually through all ages by the action of rain water upon its surface alone. The surface of the limestone belt has been lowered both by the rain water above ground, and by the falling in of the roofs of the caverns produced by chemical solution underneath; the débris thus tumbling into the caverns being removed by the powerful streams flowing through the caverns. In the limestone belt the purely mechanical surface erosion is much less than in the slate belt, because so little water flows over the surface, what few brooks and creeks there are mostly disappearing into crevices and sink-holes. The superior energy of this *chemical erosion* is shown by the mere fact that the limestone plain, with all its advantages for resisting erosion, has actually been eroded 200 feet lower than the slate belt. This is wholly due to the formation and destruction of caverns. The limestone country, then, is worn away by the chemical solution of its more soluble beds, and the tumbling in of the others; while the slate country is worn away by the mechanical cutting down and widening of ravines open to the air. The débris from both is removed by the powerful streams, above ground and under ground, swollen by rainy seasons, by the melting of snow, and by violent tempests.

The old idea that the land surfaces have been produced by sea waves has been discarded; and, with regard to the two plains of Northampton county, composing side by side the floor of the great Kittatinny valley, but the one 200 feet higher than the other, it is evident that the ocean has had no hand in their formation.

Drift deposits of the limestone belt.

Professor Prime suggests in his report a possibility that the remarkable general levelness of the limestone plain may be partly due to a *drift deposit* covering portions of the belt, concealing rocks, rendering it impossible to observe

outcrops, to take dips, and consequently to ascertain the structure.

This *drift deposit* must not be confounded with the "*Northern Drift*" which covers New England, New York, New Jersey and Pennsylvania down to the line of the Terminal Moraine, and so far as Northampton county is concerned the slate country between Belvedere and the Blue mountain.

The *drift deposit* which helps to give a plain-like aspect to the limestone belt is not *unstratified glacial moraine matter*, but is a superficial bed of stratified sand and gravel distributed by and in water. Prof. Prime describes it thus: "Where the rock outcrops are scarce or wanting, the road is usually found traversing gravel, sand, fine clay or quartz bowlders," the study of which is "extremely difficult and unsatisfactory, owing not so much to the paucity of the exposures as to the extremely limited depth to which any of these exposures has been opened." On this account and because of the uncertain horizontal extent of area covered by such deposits where they were noticed it was thought best not to attempt any representation of them in color on the Six sheet map, except at the only two typical localities where they are artificially shown to advantage, viz: on the hill top at West Bethlehem and on the hill top at Easton.

Rauch's sand and gravel pit at West Bethlehem shows alternate layers of sand and of mixed sand and gravel. The gravel is a heterogoneous mixture of rocks in which those of a quartzose character naturally predominate. There are rounded pebbles of *Oneida conglomerate* and *Medina sandstone* from the ribs of the Kittatinny mountain; of *Oriskany sandstone* from the Walpack-Godfrey ridge at Stroudsburg, or Rocky ridge north of the Lehigh Water Gap; of grey and red *Catskill sandstone*, either from Pike county or else from the Second Mountain on the Lehigh above Perryville in Carbon county; and even of *Mauch Chunk red shale.*

Were these last correctly identified with certainty the whole deposit would have to be referred rather to waters descending the Lehigh valley than to waters descending the

Delaware valley; for no *Mauch Chunk red shale* (Formation No. XI) is to be found in Pike and Wayne counties, nor in New York on the east side of the Delaware river. But there are red shales in the Pocono (No. X) and Cattskill (No. IX) which resemble those of No. XI. Therefore the original home of the deposit remains doubtful.

Mixed with the above mentioned pebbles, however, are more angular though somewhat rounded specimens of limestone, brown hematite iron ore, and flint. These probably belong to the limestone belt itself in which the deposit lies. But even if so, they might be conjectured to come from northern New Jersey on the one side, or from Lehigh county on the other. Their angularity however is an argument against their having come from any great distance.

The flints indeed might possibly come from the outcrop of the *Corniferous limestone* at Walpack bend. It is a massive formation eroded by the south bank of the Delaware river all the way from Port Jervis to Walpack bend, and continuing westward past Strousburg, must have furnished flints in abundance to the lower country of eastern Pennsylvania. On the other hand the *Corniferous* outcrop on the Lehigh in Carbon county is only 5 feet thick; so that if the flints be really *Corniferous* they favor a reference of the deposit to waters descending the Delaware.

Angular or *flat* pieces of *syenitic* rock are also occasionally seen in the deposit. This is a very remarkable fact, and it calls for special notice; for they could not have come from Canada with the *Northern Drift* without being much rounded. It seems certain that they came either from the mountain side which rises opposite to Bethlehem and Easton, at the foot of which the Lehigh river flows; or from a hill of syenite which rises on the north bank of the Lehigh between Bethlehem and Allentown; or from the syenite hill north of Bethlehem. In any case, the presence of even a few flat fragments of syenite in the *drift deposit* would seem to settle the question of its purely *local origin.*

The mountain slopes of syenite opposite to Bethlehem rise southwards to summits 880′ and 920′ A. T. At the gorge through which the Lehigh flows, two miles above

Bethlehem, there is a ridge of syenite on the south 640′ and another on the north 550′ A. T. the distance being 2600′ from summit to summit across the river, which flows between them at 220′ A. T. Three miles north of the Lehigh at Bethlehem, the Manocacy cuts through a ridge of syenite, with Pine-top 600′ A. T. and Quaker hill 600′ A. T. as its two summits rising from the south-east bank of the creek, the bed of which is 280′ A. T.

The hill on which Rauch's gravel pit is, only rises to 320′ A. T. the Manocacy at its base being 220′ A. T.

The gravel pit is about 25′ deep, and under the gravel lies the yellowish clay characteristic of all decomposed limestone surface land, and under this again on the river slope crop out the limestone strata.*

The limestone upland on which Bethlehem is built is 350′ A. T. in the town and rises northward east of the creek to 380′. The hill-tops bordering the Lehigh on the north all the way to Easton, are mostly marked upon the map 360′, 380′ and 420′, and those further north, from 400′ to 460′.

It appears therefore, that the gravel of West Bethlehem is of the nature of a patch of *terrace deposit* left uneroded on top of the bluff hill between the Manocacy and Lehigh, with its bottom layer only 75′ and its top 100′ above the present level of the river. Nor is it certain that auy such deposit was spread over the general surface of the limestone belt.

By *terrace deposit*, however, must be understood either *high flood river deposit*; or else, *ancient abandoned high-level river-channel deposit.*

Much has recently been written, especially respecting the New England terraces, on the basis of a theory that the present river channels were invaded by deluges of waters at the close of the ice age, and that the terraces are the side fragments of vast deposits with which the valleys were then filled, the most of which were afterwards excavated and carried away.

But the surveys of the western and northern counties of Pennsylvania have furnished pretty satisfactory data from

*These are Professor Prime's data. See Mr. Lewis's below.

which to reject such a theory, and to support the view that the terraces are remains of river deposits previous to the lowering of the river-channels to their present level.

The gravel deposit at Easton is a repetition of that at W. Bethlehem, and lies within two or three feet of the same elevation; which is a good argument, as far as it goes, that the deposit belongs to the class of *river-terrace* deposits.

The streets of the west ward of Easton have been cut through clay, gravel and bowlders, in alternating beds, some of the bowlders being about the size of a half-bushel measure. The beds are apparently continuous. In some places there is nothing but gritty clay to a depth of 8 or 9 feet. The gravel and bowlders are all rounded, but not scratched; and the mass is not of so heterogeneous a character as at W. Bethlehem; but made up mostly of quartzose pebbles from beds in the Hudson river slates (No. III), Oneida and Medina sandstones (No. IV.)*

The gravel seems confined to a slight depression 330′ A. T. between the hill top 350′ to the north-east of it and the long slope culminating at 390′ A. T. on the road to Bethlehem, half a mile west of it. The Lehigh water level is here 160′ A. T. So that the top of the gravel here is not 100′ above *river level* as at Bethlehem, but 170′, although it lies at almost exactly the same level above *tide level.* This fact seems conclusive against any theory referring these two remarkable gravel deposits at Bethlehem and Easton to river action on the supposition that at the end of the Ice age, when the change of climate took place, and the ice sheet was rapidly melted back, the effusion of glacial waters was so enormous as to flood the continent, and put the rivers so high as to overflow their side hills and spread abroad the waters over the back country.

If the Lehigh river valley were thus filled with a raging torrent to the height of the gravel patch at Bethlehem, it would not have been filled to an equal height at Easton. The difference of the levels in the river bed would be imitated more or less closely by difference of level of the two

*Prof. Prime's description.

gravel patches. The slope of the bed of the Lehigh river would make the Easton gravel patch 220—160′=60 feet lower than the Bethlehem gravel patch. Instead of that the two are at the same level.

Even supposing that the confluence of two such floods, one descending the Delaware valley and the other the Lehigh valley, would lift the water level at Easton, and this effect would be assisted by the difficulty with which the combined flood would make its outlet between the mountains below Easton,—it is hardly possible to imagine that the levels of the two gravel patches 12 miles apart would be so exactly the same as they are,—especially when the narrow gorge just west of Bethlehem would have the same tendency to raise the flood level there.

Nothing but a damming back of all descending waters at some point below Easton would suffice to give a general flood level of 320′ at Easton and Bethlehem and everywhere else in Northampton county. But there is no evidence of such a dam, and no known means for producing it.

Ice indeed would furnish such a dam. But the Terminal Moraine, which shows exactly how far the ice advanced south-westward and where it stopped, crosses the country 12 miles north east of Easton.

But even granting the possibility of such a dam, its only effect would have been to produce comparatively still water, which would not have the power to carry forward to any point such materials as compose the gravel patches under discussion.

What other agent than river flood then could have brought down from the back country so heterogeneous a mixture of outcrop fragments referrable to formations III? IV, V? VII, IX and XI? and deposited them on low hill-tops bordering the river?

And what change of agency during the progress of the deposit is indicated by the fact that its upper part is clay, and its lower part gravel?

These questions may be answered thus:

The *Lehigh river bed may have been and we have good evidence that it was at a higher level* at the time the two

gravel patches at Bethlehem and Easton were deposited, and *that it has cut down to its present level since the ice age.*

In fact this lowering process is still visibly going on. The only question is: how rapidly does it go on? How long a time would be required for the Lehigh to lower its bed 100 feet? Could this have been accomplished by it *since the ice age?*

No answer can be given to this question in terms of solar years, or centuries; but in more general terms a very precise and positive answer can be given to it, and in the affirmative.

Northern Pennsylvania is full of *post-glacial* valleys and rock cuts, excavated to considerable depths *since the retreat of the northern ice.* Many of the pre-glacial valleys were filled up by moraine matter brought forward by the ice. But while thus obstructing the ancient rivers, the ice greatly enlarged the volume and force of their floods, and enabled them to excavate for themselves new channels, at first through the mother rocks, and afterwards through the obstructing drift.

A flagrant example of this is furnished by the little contour-line map of the mouth of the *Clarion river* in Mr. Chance's report on Clarion county Report VV, plate 3; described page 19. The old channel of the Clarion river, in the form of an S, crosses and recrosses the present nearly straight valley of the Allegheny river, near Parker, three times. The Clarion was in preglacial times the main river, and the Allegheny was a small stream heading up near Franklin, where a mountain barrier of *Pottsville Conglomerate* No. XII cut off all the waters beyond and sent them northward into Canada, as Mr. Carll's reports first made known. When the Ice sheet appeared and choked with Drift the ravines leading into Lake Erie, the northern waters overflowed the barrier and cut a gateway for themselves southward, into the little Allegheny branch of the Clarion, swelling it enormously, so that it cut its channel through the bends of the Clarion at Parker and has ever since then been the main river. *The old gravel filled bed* of the Clarion was left high and dry on the hill sides, the Clar-

ion itself grading down its own bed to suit the lowered bed of its former tributary, now its master.

The observer can here measure the depth to which a great river has lowered its bed since the ice age. Mr. Chance writes: "*The summit of this old valley [gravel] is about 1090′ above ocean level, or two hundred and fifty feet* (250′) *more or less, above low water in the Allegheny river at Parker.*"*

In consequence of the activity of the Allegheny river in its new career of erosion all its great affluents from the east, including the Clarion river, were forced to deepen their beds by undercutting their cascades; and this gives us other opportunities for the study of post glacial erosion, and high gravels.

Mahoning creek in Indiana county (see Mr. W. Platt's Report, H^5, p. 155) flowed in preglacial times around "the Cove," at Mahoning furnace, on a floor of rock 115 feet above the present water level. The Cove is merely the old bend of the stream now left high and dry on the hill sides. Post-glacial erosion has left an island of limestone in the bend of the cove, overhanging the new channel. And *both the top of this island* (a table of horizontal limestone) *and a promonotory capped with the same limestone near by*, are covered with *a layer of old gravel 25 feet thick.*

It seems as if this last case in Western Pennsylvania suffices to explain exactly Rauch's gravel patch on the hill top at West Bethlehem; while the fact that the Easton gravel patch lies in a depression between two hill tops, agrees with the supposition that this depression was formerly the actual water way of the Lehigh river.

Should we seek an ancient channel for the Lehigh west of Bethlehem, the present channel would first offer itself; but if another should appear to be shorter and more direct in its course and unobjectionable topographically, it must be preferred.

A glance at the contour-line map will suffice to show that were the present gorge below Allentown to be filled up to

*The Allegheny has subsequently refilled its new bed with 50 feet of new gravel. (VV, p. 19.)

a height of 365′ A. T. (or 110′ above R. R. grade at Allentown station, Lehigh Valley railroad, 254′ A. T.) the Lehigh would flow up the ravine east of Allentown, over the divide at Ritterville, *north of the syenite hill*, directly to the gravel patch at West Bethlehem. It is pretty evident that when the Little Lehigh river established its lines of drainage it did not flow into the gorge between the syenite ridges now occupied by the Lehigh river, but made for the north side of the syenite ridge, over the site of Allentown, It did this, doubtless, to join the Lehigh flowing then eastward by that *old channel.*

The fall of the present river bed from Allentown to Bethlehem, 5 miles, is about 20 feet, (taking the RR. levels as a guide,)=4′ per mile. The fall of the canal level from Mauch Chunk to Easton, 46 miles, is 360′.87,=7′.85 per mile.

Therefore when the ancient water level surface of the Lehigh at the West Bethlehem gravel patch stood at 320′ A. T., it stood about 335′ A. T. at Allentown, The Ritterville divide now stands at 360′+. If this be taken as the ancient course of the river, (and the map offers no other,) it is necessary to suppose a gravel deposit under or to the north of Ritterville, not merely 360′—330′=30′ deep, but 30′+27′± (the depth of the gravel deposit)=57′±; unless the river bed at Ritterville had a rock bottom and all its gravel collected in the dead water at West Bethlehem, where the Manocacy and Lehigh meet. In fact the gravel patch looks like the remains of just such a considerable river deposit as we know from a thousand examples is always made under such circumstances.

An instance is just at hand; viz. at Shimersville, two miles below Bethlehem, where the Lehigh river receives Saucon creek, through a large level-floored gap between the ends of two of the South Mountain ridges. The yellow color on the map shows what a broad level floor of detritus spreads out here; and the contour lines of 230′ and 240′ A. T. surround it, showing that its general level is 30′ or 40′ above the present water level of the Lehigh. The time is sure to come when most of this deposit will be carried away

by the deepening of the Lehigh water way, and the consequent deepening of the bed of the Saucon, and of all the small water ways which lead into it. No doubt there will finally remain a patch of deposit in the center of the area south of Shimersville; and this will very fairly correspond to the ancient gravel patch at Rauch's pits on top of the West Bethlehem hill. To see the resemblance between the two cases it is only necessary for the eye to follow the 320′ contour line around Bethlehem and West Bethlehem, and see how it encloses what must once have been a similar plain at the junction of the Manocacy and Lehigh.

The gravel patch at Easton looks like the fragment of another such gravel plain at the junction of the Lehigh and the Delaware.

The Bushkill has evidently flowed through *ancient channels* at a much higher elevation than it does now, and has changed its course repeatedly, and cut a recent gate for itself through Chestnut ridge, instead of flowing around the west end of the ridge as it had previously done. And all this without apparent interference from the moraines of the ice age no trace of which exist in this neighborhood. At least, such are the conclusions to be drawn from a study of the remarkable sink hole valley described already on page 16.

We are relieved then of all necessity for inventing vast floods raging madly down the Lehigh valley, overtopping the side hills, and spreading over the back country. The parallel is perfect. For the localities of Parker and Mahoning furnace are as far south of the line of the *terminal moraine* as the localities at Easton and Bethlehem; while the post-glacial deepening of the Lehigh river bed, called for, is not 100 feet; while that actually accomplished by the Allegheny river is more than double that amount; both having taken place in the same length of time; but the Allegheny river being much the larger of the two streams.

We get, moreover, in this way a lucid explanation of the embarassing fact that only these two gravel patches are *certainly known* to exist in the limestone of Northampton

county*; and of the still more embarassing fact that both of them lie in positions least likely to afford them protection, viz: on hill tops immediately overlooking the Lehigh river. For these are the very places where patches of an ancient elevated bed of the Lehigh should be looked for; and as the river cannot have meandered vaguely over the limestone belt, but must have clung to the South Mountain slope, we have no call to look for fragmentary patches of its old channel at any distance north of its present banks.†

We may dismiss then the idea that the general flatness of the limestone belt is due in any respect to a supposed covering of any kind of *local drift;* and if there actually exist patches of sand and gravel back from the river, they must be ascribed to small streams which perhaps in glacial times, flowed southward from the slate region over the limestone surface. The very contour of the surface of the limestone belt, moreover, is such as to set at rest any suspicion of a wide spread surface deposit, which, if it had been laid down in any kind of water, would have filled up the inequalities and made the rolling country a nearly dead level plain gored into deep and narrow sand ravines.

The greater fertility of the limestone belt compared with that of the slate belt is of itself sufficient to prove that the limestone rocks are not concealed under any considerable layer of foreign sand and gravel; for its extra fertility is due to the fact that the soil is a decomposition of the lime stone rocks.

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*It must be kept in mind that the discovery of these two gravel patches is due to the fact that two such cities as Bethlehem and Easton use much sand and gravel, and get it close at hand if they can. There may be plenty more further off which is never touched and in fact remains undiscovered.

†*Post-glacial rock-cuts* made by the Wallenpaupack and Shohola creeks in Pike county, are well described by Prof. White in report G6.

The post-glacial rock-cut made by the imprisoned Aquanchicola creek just behind the Lehigh Water Gap is another case in point well deserving of close study, in connection with the sand-dam thrown across the mouth of the valley behind the Red hill.

The subject takes a wide range: I will only take occasion to suggest here that the Eddy hills, described in my Coal Manuel, for instance that in the Bald Eagle Mountain gap near Williamsport in Lycoming county, may perhaps be explained by the gradual cutting down of the gap to keep it at a level with the Susquehanna river, as the latter lowered its bed.

Supposing it proved, however, that Rauch's gravel lay in an ancient higher channel of the Lehigh river, we are far from having settled all the difficulties of the subject. There remains the questions of 1. what was the actual depth of the deposit, *i. e.* how high did it reach above the present hill top? and 2. why are its upper and lower divisions different?

Rauch's hill top is certainly not as high as it was. How much of it is gone?

Mr. H. C. Lewis in his Report on the Terminal Moraine (Z) gives the following section:

Rauch's gravel pit.

Top, 320′ A. T.=100′ above the river.	
Clay holding bowlders, large and often sharply angular, lying irregularly in the body of the clay. Of this clay there remains on the hill top, as quarried, ...	4′
Gravel and sand, horizontally stratified; destitute of bowlders; the pebbles all *water worn*, never more than 3 or 4 inches long, ...	
Streaks of *pure sand*, ...	
Sand with oblique stratification.	
Gravel and sand, stratified, but not horizontally; gray, sandy, *no clay.*	
Bottom of the pit, ...	30′+
	34′+

Mr. Lewis saw no limestone clay under the gravel.

The *bowlder-clay* limit (upward) he finds plainly marked at the Lehigh University in S. Bethlehem at 180′ above the Lehigh river.

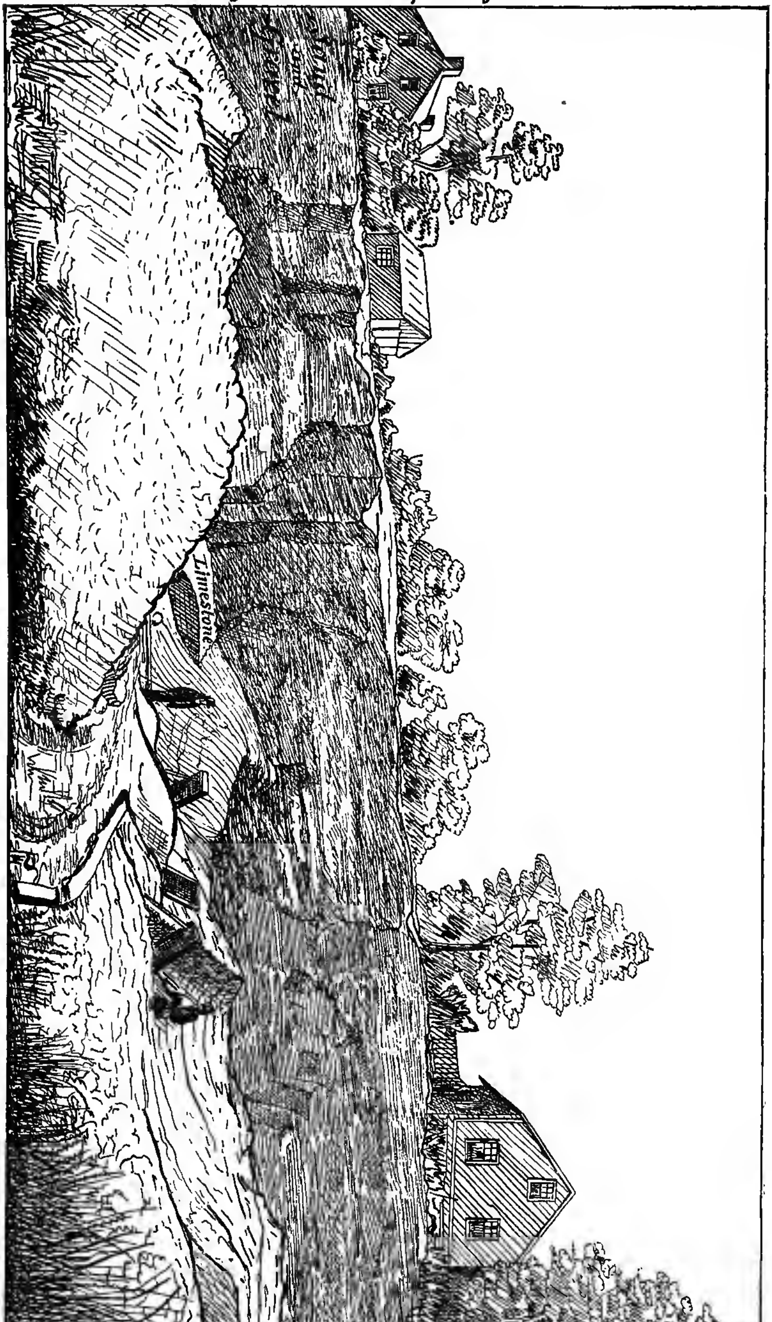
In Carbon county at Weissport he found a bowlder of conglomerate 6 feet long lying on the hill side 180′ above the Lehigh river.

In Bucks county at Yardleyville, near Trenton, he makes again the upper limit of the bowlder clay (near the toll gate) 180′ above the Delaware river.

And again at Somerton in Philadelphia county, 180′ above the Delaware.

The hill top, at Rauch's quarry, then should have been originally 80′ higher than now, and the bowlder clay 84′ thick, if there were any regularity in such a deposit. But this is against all experience on both sides of the Atlantic. Neither top nor bottom of bowlder clay bears much refer-

Second Geol. Survey Pa. Rauchs quarry. 1883. D.3. 49.



ence to topographical elevations anywhere. The four local maxima of 180′ mentioned above are of course on a downward slope corresponding to the water bed slope of the Lehigh and Delaware rivers; and it is hard to see what use they can be put to in the general argument. But the presence of bowlder clay as high as 400′ A.T. (180′ above the river) at South Bethlehem, only a mile from Rauch's gravel pit in West Bethlehem, certainly allows us to conclude that the 4′ of bowlder clay at the top of the gravel pit is only the remnant of a very thick deposit overlying the gravel deposit, and as distinct from it in origin as it is later in age.

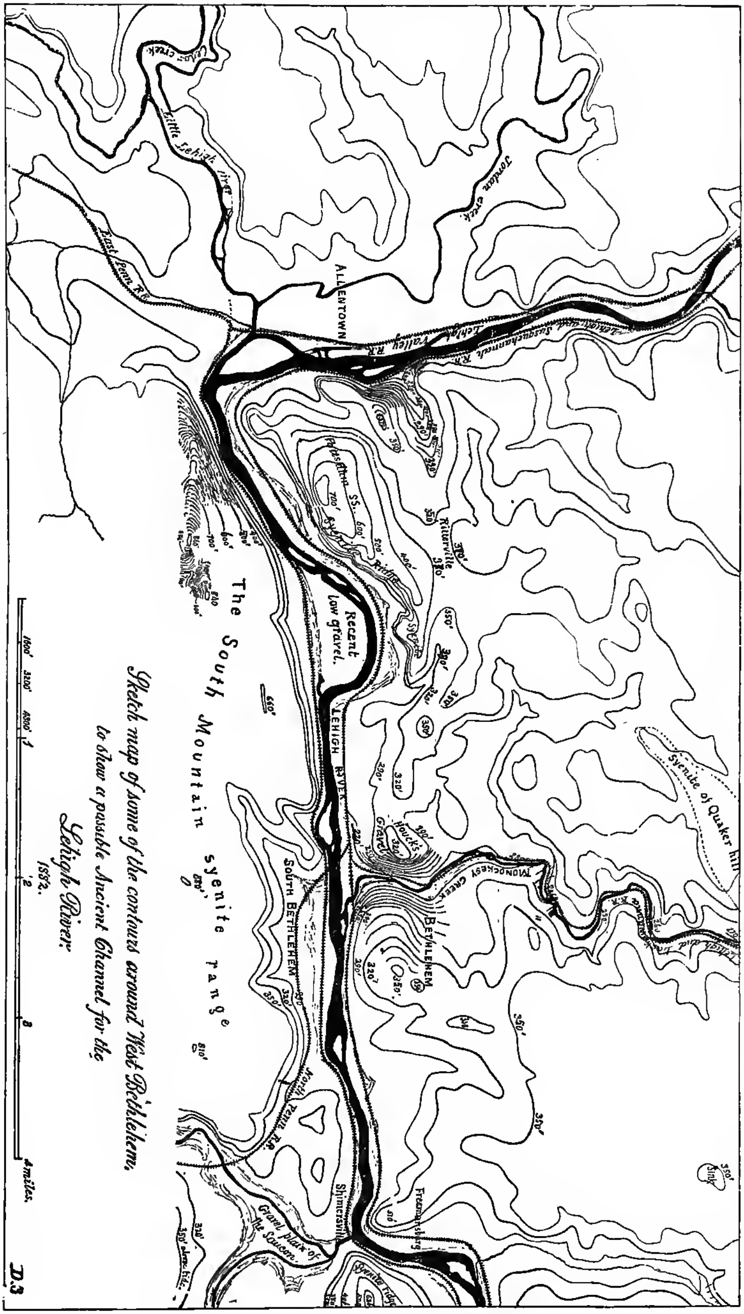
If the bowlder clay be glacial, the underlying gravel and sand is certainly fluviatile. The ancient Lehigh undoubtedly deposited the gravel and sand; and then afterwards the bowlder clay was deposited on top in some quite different manner.

But not only has Rauch's hill been much higher than now because the bowlder clay deposit was much thicker than 4 feet; the older previous river sand and gravel deposit was thicker than it is now. This is shown by the irregularity of its upper line. Its top surface had been worn into hollows and partially removed before the bowlder clay which now occupies these hollows was deposited upon it. This is another proof that the two deposits are of different ages and that some great change must have happened to the climate, or to the country.

A rise of the sea level, a submergence of the continent, is invoked by many now to account for similar deposits.

The fact of such a rise in connection with the Ice age, seems to be proved beyond all doubt by the finding of stratified shaly clay, containing arctic shells, lying between an upper and a lower bowlder clay, at an elevation of 512′ A.T. at Airdric in Scotland.* The water of course may have stood at any *greater* height than the bed itself in which the shell fish lived; and British glacialists think they find evidence of a rise of the sea level to 1500′ A. T. But 700′ or 800′ will suffice in eastern Pennsylvania to explain some things.

* See Geikie's Great Ice Age, p. 185, New York Ed. 1877.



Sketch map of some of the contours around West Bethlehem, to show a possible Ancient Channel for the Lehigh River. 1882.

The Bryn Mawr and other 400′ A.T. level gravel patches of Bucks and Delaware counties show that there was once a rise of the sea level *to that height* at least. Whenever it may have occurred, the valleys of the Delaware and Lehigh in Northampton county must have been arms of the sea into which would necessarily be dropped all the stuff which those rivers brought down from the north; and if this rise happened after the formation of the moraine, or during the prevalence of the great ice field, these valleys must have become filled up to a high level with glacial clay, in which, no doubt, would be included large blocks of stone from the moraine.

The conglomerate bowlder at Weissport lies (180′+river; R. R. station level 475.5′,) about 650′ A. T.

Bowlders lie scattered about the surface of the slate belt in Northampton county, and one especially remarkable locality is the isolated slate hill at Mooresburg, 5 miles S. S. W. of the Wind gap, from which a noble panoramic view can be obtained. The top of this hill is covered with bowlders. Its precise height level is not known, but cannot be less than 700′ A. T.

But no clay is seen in connection with these *bowlders.* Therefore the distribution of the bowlders over the surface of Northampton is to be accounted for entirely apart from any explanation of the deposit of the clay.

On Rauch's hill therefore we have three quite different things:—1. The gravel and sand deposits of the ancient Lehigh;—2. A thick deposit of clay on top; and—3. Large angular bowlders accidentally present in the clay, and to be accounted for differently. The English glacial theory of *Till* or bowlder clay formed *under a glacier* and ejected at its end, or left behind upon its melting away will not explain the *bowlders without clay* scattered more or less thickly over the surface of Northampton county.

But the same sea which submerged the land to a height of at least 800′ A. T. would serve to deposit the clay brought down from the Moraine covered north, and at the same time would serve to float small ice floes from which the bowlders (taken also from the moraine) would drop into the clay,

where the clay had already been deposited, and open the the bare rock surface where the clay had not been deposited.

This is perhaps the nearest we can at present come to an explanation, although it is far from being satisfactory. But its defects may be diminished by considering 1. that the age of submergence must have been a short one; 2. that the time of rise and the time of fall may have been very different; 3. that when the sea stood at 300′ it would tear off and float away ice masses with moraine matter from the great glacier at Belvedere; when it rose to 500′ A. T. it would cover the limestone belt of Northampton county, and penetrate into Carbon county (as a tide way) as far as Mauch Chunk; at 700′ A. T. it would submerge a good part of the slate belt, and wash with its breakers the whole front of the moraine north of Belvedere; and at 978′, if it rose so high, its waves would beat across the floor of the Wind gap.

A great objection to all this is that the bowlder clay does not look at all like a marine deposit. The absence of shells may be explained by the intense cold of the water and the impossibility of the immigration of arctic forms at short notice and by a southern route. But the absence of stratification is serious against the theory.

To sum up the case:—1. Rauch's gravel is an ancient river-bed deposit. That is certain.

2. The river was the Lehigh flowing at an elevation of 100 feet higher than at present; and probably north of the syenite ridge; south of which it has since then cut its way by removing the limestone rocks and the Potsdam sandstone. For, if the present Lehigh were to be swollen by 100 feet of flood water, it would remove the gravel from Rauch's hill instead of depositing it.

3. The whole limestone surface of Northampton county has been lowered correspondingly; and all its streams have cut deeper, and changed their channels locally, since the deposit of Rauch's gravel. The rock-cut of the Bushkill, back of Easton, has also been made since then; and possibly the rock-cut of the Delaware.

4. Rauch's gravel is only a fragment of a considerable gravel plain at the junction of the Manocacy and Lehigh,

like the one more recently formed, at a lower level, and less worn away, at the mouth of the Saucon.

5. A change came with the Ice age. The climate became arctic; the ice sheet gradually descended from the north as far south as Amboy, Belvedere, Hazleton, Berwick, and Ralston; the Terminal Moraine was left on its retreat; the whole country back of it remained covered with Drift; the thousand affluents of the Delaware and Lehigh rivers brought the materials forward.

6. Probably the sea level rose and covered eastern Pennsylvania during the continuance of the ice.* The action of the wave against the moraine, the sailing off of icebergs, the torrents of muddy water from under the ice, combined, would sift out the clay of the moraine and deposit it on the submerged surface of the country in front, dropping also bowlders.

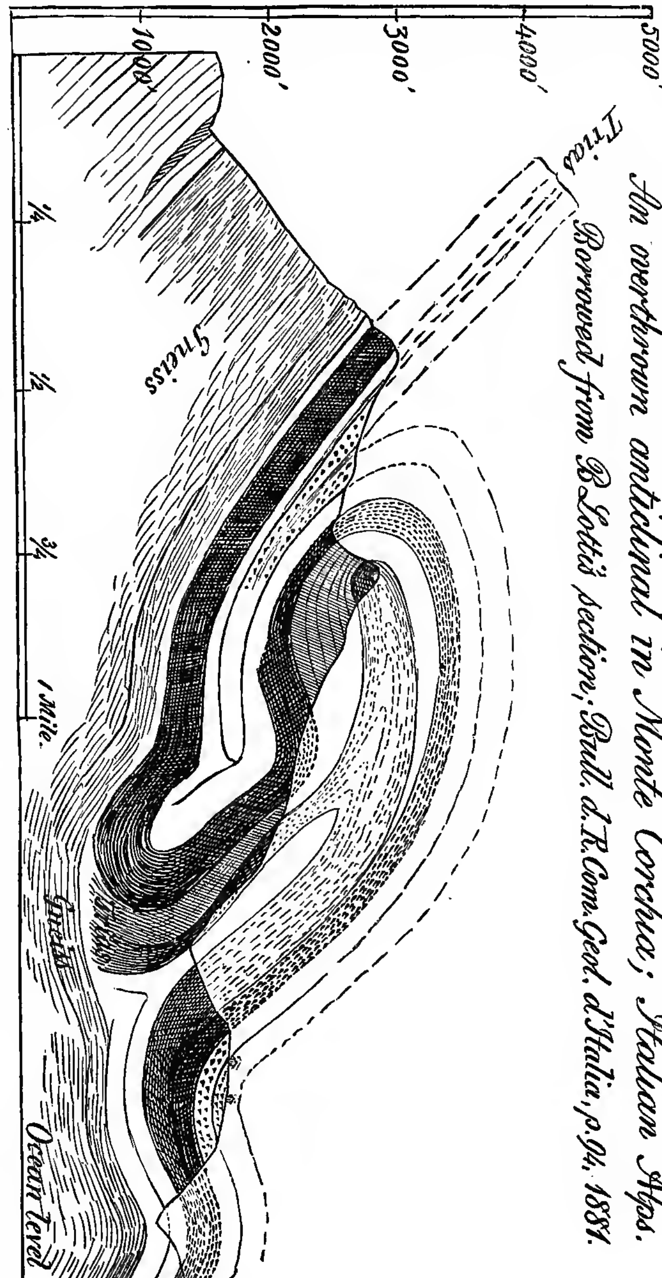
7. Most of this deposit has been removed by ordinary rain water erosion and the continued lowering of the surface, since the ice age; but probably much of it remains undiscovered, because there is no call for sand and gravel in large quantities except in the immediate vicinity of large towns and cities.

The internal structure of the limestone belt.

Level as the general surface may be, it is the planed-off section of as gnarled and twisted a piece of the earth's crust as can be found in any country. Although these plications are comparatively small they are of the same nature as the gigantic overthrown anticlinals of the Alps and Appenines, a specimen of which is given on the opposite page, p. 55.

The arrows on the Six Sheet Map show that the several beds of limestone, composing a mass several thousands of feet thick, are uptilted at all angles, twisted and contorted in every direction, and probably lapped upon each other like a folded carpet. At first sight there is no discoverable order or arrangement to be made out from the occasional

* While the abstraction of water to make the ice sheet must have lowered the general sea level of the world, the weight of a continent of ice 5000′ thick would shift the center of gravity of the globe and cause the flow of water from the Antarctic hemisphere to raise the sea level at the north.



An overthrown anticlinal in Monte Corchia; Italian Alps.
Borrowed from B. Lotti's section, Bull. d. R. Com. Geol. d'Italia, p. 94. 1884.

To illustrate plications in the Siluro-Cambrian limestones and slates in Northampton Co.—D. 3. 1882.

exhibitions of the rock in the fields, in quarries, in railroad cuttings, and in the banks of streams.

The lower beds of the mass certainly dip away from the sides of the mountains and syenite ridges towards the plain; and the higher beds of the mass certainly dip towards the slate belt and pass beneath it. But the rate of dip in both cases varies infinitely; being sometimes almost vertical and at other times almost horizontal. And the directions which rocks take in going down show the most curious and embarrassing deviations for a direct and regular descent. There are cases where the dip is east or west, just where one expects to find it north or south; and that in close proximity to dips which are all right.

Two examples of this may be cited, viz: the *west* dips on the north bank of the Lehigh at Easton, where all the rest are south; and the *east* dips near the slate border, west of Martin's creek, where all the rest are north.

The only explanation for such facts is to be found in a *bunched structure*, analogous to (but the reverse of) the *dimple structure* of our coal measures. Such a bunch, or little dome of limestone, is shown by the circle of arrows around the pimple hill a mile east of Weaversville.

Parallel anticlinal and synclinal rolls and troughs certainly traverse the belt lengthwise. But most of them are short and irregular and many of them compressed and overturned northward, as seen in the quarries along the Lehigh, mentioned on page 36 above.

Large anticlinal waves and synclinal basins, however, can be made out by grouping the dips on a large scale; and these form the principal structural feature of the belt.

The limestone belt divides itself largely into two and a half synclinal troughs.

Anticlinals and synclinals.

The southern synclinal occupies the whole space between the South mountains as its southern border, and the line of Chestnut hill, Quaker hill, Pine knob as its north border.

The trough in which the Lehigh flows from Allentown to Bethlehem and Shimersville, and the trough in which it

flows below Freemansburg, are parts of it, separated from the main body by the Allentown syenite ridge, and by an anticlinal axis which runs along $\frac{1}{8}$ mile north of Hopes.

The middle synclinal lies north of Chestnut hill and Quaker hill, and is bounded on the north by the broad anticlinal which crosses the Delaware in the great bend, and the great anticlinal which crosses the Lehigh a mile above Catasauqua. These are distinctly traceable for several miles west of the Delaware and Bushkill and east of the Lehigh; but can be joined only by a series of indications $\frac{3}{4}$ mile north of Hanover, and just south of Smoketown and north of Newburg. There is evidently, however, one main line of anticlinal uplift all the way from the Delaware to the Lehigh.

The northern half-synclinal of limestone borders the slate belt, and is deeper than the other two, because it receives and holds the lower members of the overlying slate formation. The other half of this synclinal runs along under the slate-border hills. The anticlinal which bounds this synclinal on the north brings up to the surface the limestone area of Kreidersville, and the patch of limestone on Catasauqua creek 2 miles above Weaversville.

The limestone formations.

The Trenton limestone formation includes the uppermost limestone beds, which sink northward beneath the slates. They are best exposed along the Delaware at Martin's creek, on the Bushkill above Stockertown, on the Manocacy at Bath, on the Catasauqua above Weavertown, on the Hokendauqua at Kreidersville, and on the Lehigh at Siegfried's bridge. Quarries have been opened at Bath and elsewhere along the line for supplying the farmers who till the soil of the slate hills to the north; because the *Trenton beds* are non-magnesian, and make a very pure and strong lime.

The Chazy limestone formation underlies the Trenton beds.

The Calciferous limestone formation underlies the Chazy.

These two great magnesian limestone formations, distinguished from each other in New York state by their quailties and by their fossils, cannot be distinguished from each

other in Pennsylvania, except with great difficulty. They form one great formation several thousand feet thick, lying directly upon the *Syenite floor*, and rising upon the foot slopes, and sometimes high upon the flanks of the *Syenite ridges*.

Potsdam. In some places there intervenes between the base of the limestone and the syenite rocks, 20, 50, or 100 feet of sandstone which represents the Potsdam formation of New York, as will be shown in a subsequent chapter.

The Chazy and Calciferous limestone strata are exposed finely along the banks of the Lehigh river between Hokendauqua and Allentown, by a range of extensive quarries worked for the use of the iron furnaces. The strata are not all highly magnesian. Some of them are almost as pure limestone as those of the Trenton formation. And what is very remarkable the magnesian and non-magnesian strata alternate with each other in the quarries, so that a selection of certain purer beds are made for fluxing the furnaces. This phenomenon has been investigated by the Geological survey, and the analyses of a long series of beds showing the alternation are published in Mr. McCreath's report of the work of the laboratory at Harrisburg (MM. 1879, page 312 and onwards) to which the reader is referred. A similar investigation on the Lehigh would no doubt yield similar results.

Whether the Serpentine and other magnesian minerals found at the base of the formation along the south flank of Chestnut hill, north of Easton, belong to this formation or not is still an open question; but some of the lower beds of magnesian limestone seem to have been metamorphosed into a crystalline dolomite in the vicinity of the syenite rocks.

The Easton synclinal.

To make clear all that has been said above, a short description will now be given of the limestone rocks of the southern synclinal in which the Lehigh and Delaware rivers flow and meet at Easton; for a single section here will serve to illustrate the whole belt, west to Allentown; and will

serve better than any section on the Lehigh above Allentown, because the rocks are extraordinarily folded together there so as to conceal the real shape of the synclinal; whereas in the vicinity of Easton the large trough structure is pretty plainly revealed.

In doing this the arrows on the map around Easton will be chiefly depended upon, although a few of them may be erroneously designated, the cleavage planes being mistaken for stratification.

Professor H. D. Roger's description of the locality in the first volume of his Final Report on the First Geological Survey of Pennsylvania, published in 1858, will also be quoted, so far as the facts are important for setting the structure in a clearer light.

The dips observed along the Delaware above Easton are S., S. 10° E., S. 20° E.—(beginning at the north) 62°, 59°, 60°, 58°, 82°, 62°, 64°, 64°, 64°., (the last three along the north bank of the Bushkill, under the College hill), 44°, 65°, 44° in the south bank of the Bushkill, opposite the west end of College hill.

The dips 1½ mile back from the river, are S. 20° E. 51° in front of the Bushkill gap; 23°, 34°, ½ m. S. of the gap; 25°, 26°, 26°, on the bank of the N. Lehigh, a mile above its mouth.

The dips on the south bank of the Lehigh are S. 20° E. 16°, S. 69°. and S. 5° W. 55°, the last at the west foot of Mt. Pisgah. This irregalarity is due to crimpling. But the abnormal dips on the north shore ½ m. to 1 m. up from the mouth, viz: S. 70° W. 28°, 28°, 4°, and 30°,—immediately followed (in 400 feet up the river) by S. 10° E. 26°, are very remarkable.

The dips on the Delaware south of the Lehigh, (beginning ⅓ mile S.) are S. 20° W. 40°; S. 20° W. 56° (both in the same quarry); S. 10° W. 36°, 22°, the last ⅗ mile south of the mouth of the Lehigh.

Here the dips change to N. 10° to 30° W., 24°; 28°; 20°; 38°; 48°; 43°; and 38°; close to the Potsdam (60°) at the foot of Morgan's hill.

Referring these to a cross line through Mount Pisgah, we

can construct a section, which shows plainly enough that the synclinal is not a simple one, but has many concealed rolls and faults, and that some of the steep south dips are probably overturned and flattened anticlinals.* The sections given on page 65 are not in the least to be relied on as showing the true structure, but only as showing the strength of the dip wherever observed, and the approximate status of the anticlinals and synclinals. As the several beds cannot be identified it is evidently impossible to make really correct sections from the most carefully observed dips. The diversity of strike is also an impediment.

The Easton synclinal, as a whole, ends in a point eastward between two of the New Jersey mountains.

The lower limestone beds overlying the serpentine of Chestnut hill, are siliceous and highly magnesian, with bands of nodular chert. Fragments of chert abound in the soil to the north and northwest of Easton, and the locality was a famous manufactory of arrow heads in Indian times.

The upper beds in the middle of the trough south of the Lehigh have been extensively quarried to make good lime for the farmers of Bucks and Northampton counties.

H. D. Rogers' Delaware river section.

Southward from Easton.

The section along the Delaware from Easton south to the village of Monroe, is described by Prof. H. D. Rogers, with a diagram, on page 98, (Geol. Penn. Vol. I,) under the heading "Stratification of the South mountains." The observations there recorded belong to the history of the First Geological Survey and possess a permanent value, apart from the theoretical views which they were made to support. They are in substance as follows:

At the mouth of the Lehigh dark blue, ferruginous limestone beds: strike irregular; dips averaging 25° to the S. 20° to 45° W.; rock somewhat metamorphosed; massive, free from joints; cleavage dip S. 40° E. 60°.

Dip steeper for ⅝ mile down the river.

* Prof Rogers suggests the possibility of two rolls between the Lehigh and the foot of Chestnut (Wolf's) hill. Geol. Pa. I, p. 242.

Dip changes to north, 20°.

Approaching Lehigh hill (Morgan's hill) limestone beds become more altered and slaty; partings filmed with mica; cleavage more conspicuous than bedding; *cleavage strike here notably abnormal*, neither coinciding with the rock-strike of the palæozoic, nor of the gneissic beds; gneiss strike (bedding) in this district being N. 50° to 45° E.; palæozoic strike (bedding) N. 65° E.; cleavage strike in limestone more east and west; but still steep to S. E.

Beyond the last limestone seen, 500′ concealed; then—

Potsdam rocks, highly altered; first, fragments and masses of siliceous slates and sandstone, none in place.

Under these rise (southward) massive beds of grey quartzose conglomerate porphyry; altered; pebbles, pea and nut size *in fused contact with* a syenite gneiss (feldspar and augite,) and its own paste containing regular feldspar crystals.

Then the anticlinal arch of granitoid gneiss with thin injections of syenite.

On the south side of the anticlinal appear again the Potsdam altered sandstones and shales, some beds porphyroidal; dip S. E. 35°.

The anticlinal arch is *double;* two arches with an included synclinal trough, narrow and compressed, holding the lowest beds of limestone.*

The north dips seem steeper in the gneiss than in the Potsdam rocks, "implying a movement of the older rock before the deposition of the materials of the newer. In other localities, embraced within this line of section, the want of parallelism is better displayed."

Next a small trough of limestone; then a pointed spur of gneiss, and

Next a wide, smooth limestone valley; trough contracting westward; not simple, but subdivided by two or more anticlinal rolls in the limestone.

Ripple marks "on a superb scale" on the limestone beds at the quarry close to Uhlersville.

Next Bucher hill syenite ridge; dip of gneiss rocks gen-

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*Note.—This refers to the little limestone cove at Iron ore mine No. 42, facing westward to the Lehigh river.

erally S. E. averaging not over 45° ; two or three folded anticlinals, their axial planes dipping S. E. ; gneiss generally greenish, and white feldpathic.

Next the Durham creek limestone valley skirted by one or two Potsdam exposures.

At Durham furnace good exposures ; regular anticlinal roll between Durham furnace and the creek.

Durham bone cave is in the steeper north leg of the anticlinal arch, "which will be found, I think, to be the prevailing position of those limestone caverns in the valleys of the Appalachian chain." It is about 300 feet long, 4′ to 6′ wide 12′ (average) high ; floor descends from the mouth inward ; walls rough ; stalactites few ; water in the floor influenced by the river level, half way down a lateral gallery ending in a T ; main gallery runs generally S. W. turning S. near its end ; anticlinal roll 20 yards S. E. of the entrance ; cave and axis of roll parallel ; fossil bones found in the floor.*

Next, the Durham hill, 1 mile wide ; a double anticlinal, with a shallow synclinal of slate and limestone ; flanked next Durham creek by a narrow outcrop of Potsdam, under limestone.

Nonconformity of Potsdam on Gneiss is here evident ; see Fig. 4, Geol. Penn., I, p. 100, reproduced on page 63 opposite.

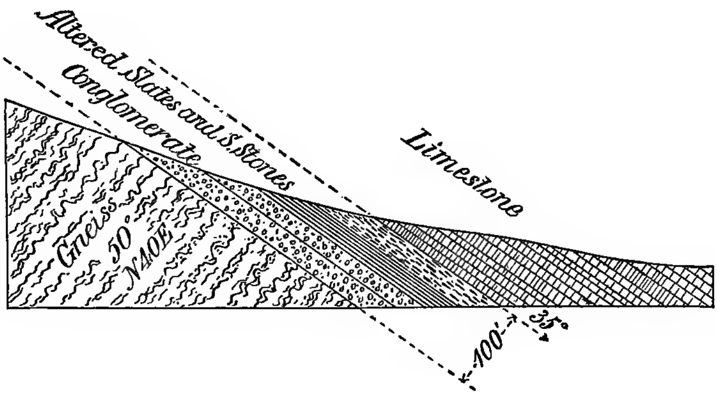
Syenitic beds, at the north base of the hill dip S. 40° E. 40° ("the inverted leg of a folded anticlinal" ?) ; Potsdam beds 100 feet thick dipping nearly opposite N. 35° W. 35° ; dark siliceous conglomerate, overlaid by alternate beds of white sandrock and alterd siliceous slate ; over which lie conformably limestone beds. Near the road the gneiss strikes S. 50° W. and the Potsdam &c., S. 60° W. nearly 20° off.†

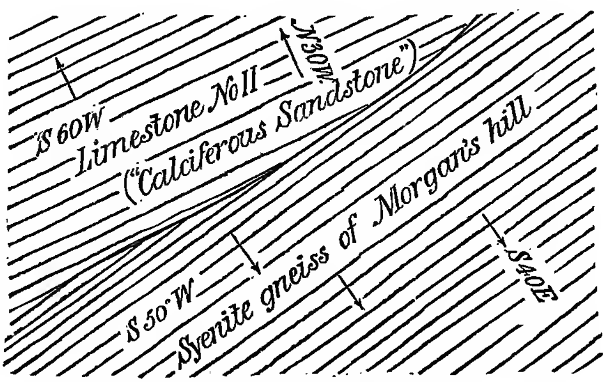
On the south base of the hill, is a narrow outcrop of white magnesian limestone greenish talcose slate and blue limestone ; then the New Red.

* Geol. Penn. I, p. 236.

† So in the text.

Unconformable contact of the Primal Rocks and the Gneiss, below Easton, Penn'a.





Ground Plan.

From Geol. Penna 1858. Vol. I. p. 100. D3.

Delaware section, northward from Easton.

The limestones north of Chestnut hill are exposed in many places on the river bank, from 1 mile above Chestnut hill gap, for 3½ miles up to Martin's creek; and for two miles further; above which river mud and drift gravel conceal them.

A synclinal trough of limestone lies north of Chestnut hill, 1½ miles broad. Near the base of the hill the beds descend nearly perpendicularly northward. Beginning a mile up the river, north of the hill, they dip N. 10° to 30° W., 70°, 63°. 82°, 76°, 66°, 68°. There must be about 5000′ of limestone rocks here descending northward; and yet the basin is not deep enough to take in the lower beds of Hudson river slate.

This synclinal can be traced by the north and south dips westward across the Bushkill, and south of the sink-hole described elsewhere.

The next dips on the Delaware are S. 10° E. 40° and S. 25° E. 48°. Then S. 26°; S. 20° W. 36°; and S. 40° W. 24°.

Here an anticlinal crosses the river which passes (two miles west) between dips of southward dips of 35°, 38° and 29°, and a northward dip of 30°. On the Bushkill, half a mile further, are S. dips of 36°, 30°, 33°, 24° and a N. W. dip of 48°.

The axis passes just through the sink-hole, (half a mile further) with north dips of 79° diminishing westward to 38°.

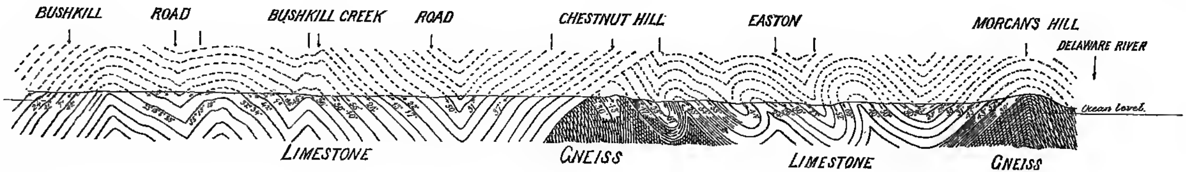
The next dips on the Delaware are first 10° and 23° and then 48° and 51° all northward.

Beyond this the river flows in a trough westward. This is the second synclinal.

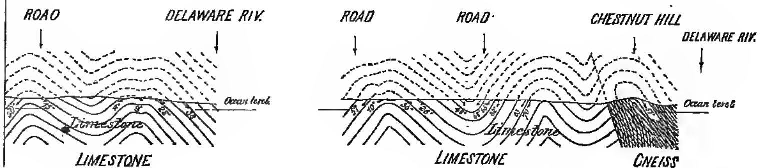
Higher up and within half a mile of Martin's creek a second anticlinal crosses the river, with south dips of 30° &c., and north dips of 26°, 34°, 22°, 8°, 4° and 12° at Martin's creek.

On the road a mile further north and near the edge of the Slate country north dips of 50°, 42° appear on the hill half a mile west of Martin's creek. But from there on west extraordinary *east dips* appear along an entire mile of road; 15°, 13°, 21° and 21°. What is still more extraordinary sim-

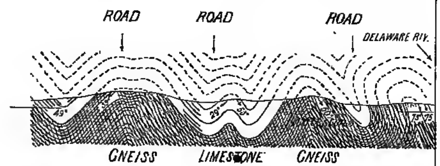
Dips observed along a line from Stockertown through Easton to the Delaware River.

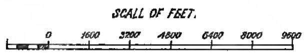


Dips observed north of Chestnut Hill.



Dips observed south of Morgan's Hill.





Note.—These sections do not give the exact positions of the anticlinal and synclinal axes, nor the actual shapes of the folds; they merely indicate the plicated condition of the country by showing observed dips at the surface.

D3.

ilar *east dips* again appear two miles further west, 35° and 16°; and these occur just north of regular north dips of 24° and 29°. There seems to be no explanation of such a structure in the limestone.

Abnormal dips of this sort occur in all parts of the limestone belt not only in Northampton county, but throughout its entire length through New York, New Jersey, Pennsylvania, and the southern States. They call for a special future study. Sometimes the rocks of considerable areas of the valley dip up or down the valley, and not across it. No theory of dying and interlocking anticlinals and synclinals, whether folded over or not, has sufficed to arrange these dips into a comprehensible system. They only suggest a universal and irregular crumpling or mashing together of the beds of the whole formation, under immense pressure.

Regular and persistent anticlinals and synclinals, nevertheless, can be perceived and followed for miles, lengthwise of the limestone belt, but usually more or less diagonally across it from east to west.

Prof. Rogers (I, page 243, 244) describes the rolls on the Delaware thus:—

1. For ¾ mile north of Chestnut hill gap no exposure; then at limekiln, magnesian limestone; dip N. 85°.

2. At 200 yards, S. dip which continues until,

3. At 500 yards, N. dip, about 70°. Then

4. At 600 yards, S. dip.

5. At 800 yards, N. dip, 60°; which continues to

6. At 1000 yards, S. dip, about 50°, becoming 40°, 30°, 20°; last flaggy limestone; which continues exposed, and gradually arches over to N. dip at the great bend of the river; a beautiful broad regular anticlinal arch. This is the first anticlinal described above, as traceable across Bushkill creek. The north dips are well exposed at Mineral Spring Hotel 5 miles from Easton.

7. After a mile, very obliquely across the outcrops, without exposures, another broad anticlinal; at limekilns; rock in the axis of the anticlinal dark blue, argillaceous, more thin-bedded and slaty, greatly cut up by cleavage; upper beds look like Trenton limestone.

8. After 300 feet, high cliff of Trenton beds, north side of Martin's creek; dip 30°, but rolling; cleavage nearly horizontal; rock, blue slate, with courses of blue argillaceous limestone, and fissile blue slate of even texture, like roofing slate; many Trenton fossils; exposure say 150′.

*III. The Southern or syenite region.**

The third or southern division of Northampton county, lying south of the Lehigh river, consists of parallel highland ridges, called by the people of the valley the South mountains; but by those who live along the lower Delaware river the Durham hills. They are merely a continuation of the Highlands of New York and New Jersey through Eastern Pennsylvania, ending at the Schuylkill river in Berks county, where they are sometimes called the Reading mountains.

The contoured map of the limestone belt of Northampton, Lehigh and Berks has been extended so as to include the whole mountain region south of the Valley, and the sheets of this connected map will be found in the Atlas accompanying this report. On these sheets the topography is so well shown that a description of it is unnecessary; but the geological structure will be described in a subsequent chapter of this report.

The contour-curves show that the South mountain ridges are long and rather narrow, no where sharp, and studded with numerous rounded summits seldom reaching the attitude of 900′ A. T. and never exceeding 1100′ A. T. The side slopes are often very steep. The region was once heavily timbered, but none of the original forest remains. The soil is rocky and poor, but cultivated along roads.

Between the mountains lie secluded vales of rich limestone land; but these vales are themselves hilly, and otherwise exactly resemble the limestone belt of the Kittatinny valley, of which they are outlying fragments, separated from it and from each other by the gradual erosion of the limestone

*Dr. Genth objects to the use of the term *Syenite* as applied to these mountains, because of the abscence of hornblende from the specimens collected, and prefers the term *Granulite*.

strata which once covered the mountains, and the removal of which has allowed the underlying syenite beds to appear.

The first range (Morgan's hill) is cut through by the Delaware two miles below Easton. The river here turns sharply west and flows along the south foot of the range, overhung by a very steep slope, rising to summits the first of which next the river is only 660′ A. T.; the next west 760′; and the third 820′. A spur of the range leaves its northern flank, runs west and nearly reaches the Lehigh, with a maximum altitude of 820′ A. T.

The river flows 3⅛ miles at the foot of this range, and then cuts south across a limestone cove, which heads up west between the first and second mountain range. The cove is 2½ miles deep lengthwise, and 1¼ miles wide at the river.

The second range. At Raubsville, the river cuts through the low point of its extreme east end, for it is not one of the mountains of New Jersey. From the river it runs west 3 miles and joins the first range. A deep ravine here trenches the combined mountain southward; and west of the ravine (five miles due west of Raubsville) is the high summit called *the Hexenkopf* (the Witches' head), 1030′ A. T. The summits which surround it on the south at a distance of 1¼ miles, are 700′, 750′ and 760′ A. T.—West of the Hexenkopf, the range runs on four miles further and ends abruptly at Shimersville, where the Lehigh, striking its point fair, cuts its end into a steep slope, almost a precipice, and is deflected northward past Freemansburg; returning again in its next bend to share deeply into the northern mountain slope, which here rises very steeply from the river bank to a summit 630′ A. T. Nearer Shimersburg there is a sharp little peak on the crest, 710′ A. T.—A second crest, only one mile long, runs parallel to the one last described and ¾ miles south of it, and has a similar sharp peak at its east end (2¼ m. E. of Shimersville, and 1¼ m. S. of Redington) 810′ A. T. The west end of this ridge is sheared sharp off, descending steeply from a nose 670′ A. T. to the edge of the limestone in Saucon Valley, 350′ A. T. where the Potsdam sandstone appears in the road.

West of the Saucon Valley, what looks like a continua-

tion of the southern crest of the second range, rises from beneath the limestone and swells into the mountain mass which occupies the country south of Bethlehem and ends at Allentown; the limestone of Lehigh county sweeping round its western foot. A road from South Bethlehem leading east, south and then straight up the steep slope west, passes over a peak on the crest 910′ A. T. This peak is 1¼ miles in an air line S. E. from the Zinc works in South Bethlehem. Another summit just a mile S. 10° W. from the Zinc works is 880′ A. T. South of this ⅛ mile, are two neighboring summits 940′ and 960′ A. T. from which the southern slope of the range descends very steeply to the edge of the limestone in the Saucon Valley at about 500′ A. T.—A mile west of South Bethlehem, the first or northern crest of the range rises from beneath Potsdam sandstone and attains a height of 660′ in the 1st mile, and 840′ and 860′ a mile and a half further on. A long slope then leads down to the bend of the river at Allentown.

Third range. From Raubsville the river keeps straight south across the next limestone interval (Uhlersville) 2 miles, and striking the north foot of the *Pohatcunk mountain* range of New Jersey turns sharply west, 1 mile, and then south, and passes through a fine gap in the range. *Bougher hill* overlooking the gap from the west has two summits 650′ and 620′ A. T., the road crossing between them. Bougher's hill is isolated from the rest of the range by Hoover's ravine descending north and Wolf's ravine descending south, the divide being only 390′ A. T. or about 250′ above the river.

West of this the third range is broken into summits which read (going west) 670′, 760′, 790′, 820′, 840′, 910′, and 910′ A. T., the last one being at a mountain road 7 miles from the river (at Bougher's hill) and 5 miles east of the railroad and Saucon creek at Hellertown. The nose on the south edge of the ridge, overlooking Springtown with its lime quarries, is 780′ A. T. The water in the creek in the Durham limestone valley at Springtown reads 320′ A. T.

This third range falls away and terminates 4 miles westward of the 910′ summit. The high summit N. W. of

Springtown is 940′ A. T.; the next 830′; and the last one, a mile before reaching Leithsville only 640′ A. T. Here the range practically ends, 12 miles from the river.

Fourth range. From Bougher hill gap the river keeps on the same course south 3 miles, bending a little west as it approaches Durham furnace at the mouth of Durham creek. For these three miles it is cutting through the limestone strata of Durham valley, the creek heading up close to Leithville, where is a low and narrow opening into the limestone valley of the Saucon.

For a mile south of Durham furnace, as far as Monroe (where the map stops) the river makes a gap through the fourth or *Musconetcunk mountain* range, one of the greatest in New Jersey. But in Pennsylvania its summits next west of the river are only 450′, 490′ and 530′ A. T., becoming 570′ (3½ miles), 640′ (4 miles), 520′ (5½ miles), and 530′ (7½ miles south of Springtown. It is easy to see why the Musconetcunk *mountain* has received the Pennsylvania name of the Durham *hills*, on account of the insignificance of its heights. But a little further west it resumes its mountain character and has a noble summit 2½ miles southwest of Leithsville, 980′ A. T.

South of this range the whole country is occupied by Mesozoic, or New Red red rocks, lying in Bucks county.

The stratification.

The foregoing sketch will suffice to place before the reader the main features of this southern division of Northampton county; composed of ranges of syenitic strata arched into anticlinals, and separated from each other by valleys of limestone strata troughed into synclinals.

The stratification of the limestone rocks of the valleys is visible everywhere, but in so broken and crumpled a condition that the fact of a trough structure must be chiefly taken on topographical testimony.

The stratification of the gneiss (syenite) beds of the mountains is, on the contrary, rarely to be seen. It also has to be judged of from the topographical features.

The strike of the north border of the syenite belt from

Easton to the west end of the northernmost of its ridges, 4 miles north of Reading, is S. 62° W. Curiously enough this is almost exactly the course of the long straight line of the Sharp mountain from Mauch Chunk past Pottsville to the Swatara gap in Dauphin county, S. 62½° W.

The course of the long straight Musconetcunk mountain in New Jersey is S. 59° to 60° W.—That of the summits from the Delaware river to the Hexenkopf is S. 61° W.

On the other hand the summits and crests of the individual parts of the belt, the ridges and spurs, range themselves nearly due East and West; as, for instance *Morgan's hill* (the first range) south of Easton; the Raubsville (second) range to where it joins the Hexenkopf; the two crests west of the Hexenkopf to Shimersville; and the next ridge south of them from Lower Saucan P. O. to Lower Saucon church; and the South mountain proper, from Bethlehem to Allentown, &c. There are evidently two systems of structure.—The half buried Chestnut ridge north of Easton trends S. 56° W. for 1½ miles, then 68° degrees for 2 miles to where it goes under.—The ridge east of Allentown bends just the other way, with about the same amount of deflection.

It is this double system of trend that produces the *échelon* topography so apparent on the face of the maps; and this again brings the syenite country into structural agreement with the Palæozoic country of Middle Pennsylvania, which is characterized more by its *échelons* or zigzags than by any other feature.

Numerous as the arrows are upon the map, they are wholly insufficient for the purpose of a detailed explanation of the structure of the South mountain belt.

Dips are in fact very hard to find, owing, 1, to the general decomposition of the rock surface of the country; 2, to the amount of débris on the surface; 3, to the vegetation; 4, to the massive and homogeneous character of the rocks where they are exposed, (in which case the true bed plane has sometimes been made out by observing the parallel arrangement of the minerals composing the rock;) and 5, to the cleavage.

It is probable that the two systems of topographical crests are due, the one to dip, the other to cleavage.

The anticlinal structure of these mountain ridges can be actually observed at only a few places. Elsewhere its proof depends on reasoning. But no geologist who has worked long in the region has failed to come to the same conclusion, viz: That the South mountain ranges have not only an anticlinal shape, but an anticlinal structure; and that when they were bent into upward folds they lifted the limestone and still higher strata into folds above them; but in the lapse of ages the overlying limestone and higher formations have been worn and swept away, leaving the mountains bare, but the intervening troughs or valleys still filled with them.

The character of the strata.

The gneiss (granulite) of the South mountain range, as Prof. Roger's remarks (Geol. Penn. 1858, Vol. I, page 93) differs considerably, in its constitution and features, from that of the Philadelphia region.

It is for the most part a massive rock in thick beds, looking like a feldspathic granite, but distinctly stratified. Containing very little mica it would be a syenite if more hornblendic; it is often charged with minute crystals of magnetite. In New Jersey magnetite often forms a prime constituent of the rock. Talc and cholorite is wanting; the original sediments were not magnesian; there are no belts of micaceous, talcose or chlorite slates as in the Philadelphia region. There is often a distinct parallelism in the crystalline structure; the feldspar and hornblende, often flattish in form, occupy alternate layers.

It is evident that the South mountain gneisses belong to a different system from those of the Philadelphia belt; and geologists who are familiar with the rocks of Canada and the Adirondack mountains pronounce them with confidence to belong to the *Laurentian system.*

Why they are not covered with Huronian or Cambrian rocks is not known; but the same question may be asked

in Northern New York, where, as here at Reading and Bethlehem, the Potsdam sandstone lies directly upon them.

If, as those suppose who do not accept Mr. Hall's views in his Reports C⁵, C⁶, the mica slates and chlorite slates of the Philadelphia belt *underlie* the Potsdam, and overlie the Philadelphia syenites, it is hard to see why they do not appear between the Potsdam and the gneisses of the South mountains, and New Jersey Highlands.

The anticlinal structure.

Prof. Rogers describes the structure of the South mountain belt, on the Delaware river, 7½ miles wide, as three distinct anticlinal ridges of gneiss, with their arches pressed over towards the north, so that all the dips are *south dips*, but half of them steeper than the other half.

The first anticlinal south of Easton (that of Morgan Hill) however is certainly not inverted, as may be seen by the arrows on the map; one on the north slope of the ridge, 200 feet above the river, showing the gneiss descending gently beneath the Potsdam N. W. 39°, the Potsdam at the north base, 30 feet above the river, dipping N. W. 60°. Arrows along the south base of the ridge, beginning a mile below the bend and continuing for nearly a mile, show the gneiss rocks descending very steeply into the first limestone synclinal at S. S. W. 53°, 77°, 77°, 69°, S. 77, and S. 10° E, 80°.

The *Morgan hill* gneiss ridge, therefore, looks like a broad anticlinal with gentle north dips and steep south dips. But in the absence of exposures near the bend, one good dip high on the ridge is not enough to settle the point. For we must throw out the Potsdam dip; for two other Potsdam dips close by have the extraordinary directions E. 32°, and S. E. 32°, showing an apparent non-conformity of the Potsdam on the gneiss.

As for the line of exposures a mile below the bend, another serious embarrassment makes itself felt. The sudden sweep of the dip around from S. S. W. to S. 10° E. is very suggestive of a collapsed synclinal, with its south rise thrown over northward upon its north rise. The axis of such a synclinal would lie between the arrows S.S.W.69° and S.77°;

and the strike of such an axis would carry it directly west into the head of the little limestone cove, at Iron mine No. 42*, where the edge of the limestone (with no show of Potsdam) rises upon the gneiss to the great height of 600′ A.T., the summit to the south of it being only 220′ higher.

Therefore while it is perfectly evident that the limestone once covered the whole ridge and descended southward into the limestone cove of the river, it looks as if the deposit of the limestone was subsequent to the uplift and erosion of the gneiss, the Potsdam not having been deposited at all. Close examinations might prove the contrary ; but at present the structure of the Morgan's hill ridge is left to some extent in doubt.

The Hexenkopf ridge, which ends at the river at Raubsville, shows no signs of being an inverted anticlinal at the river where the gneiss dips S. E. 56°. The gneiss is here only 500 feet wide, bordered by limestone, dipping away from it northward and south-eastward ; and no appearance of Potsdam between.

On the *Hexenkopf* two dips can be seen, one on the south brow of the summit (925′ A.T.) S.E. 29°, and one 1000 feet north of it on the northern slope (820′ A.T.) S.E. 54°. This certainly looks like an overturned *anticlinal;* but it may only be a steepening of the dip going north.

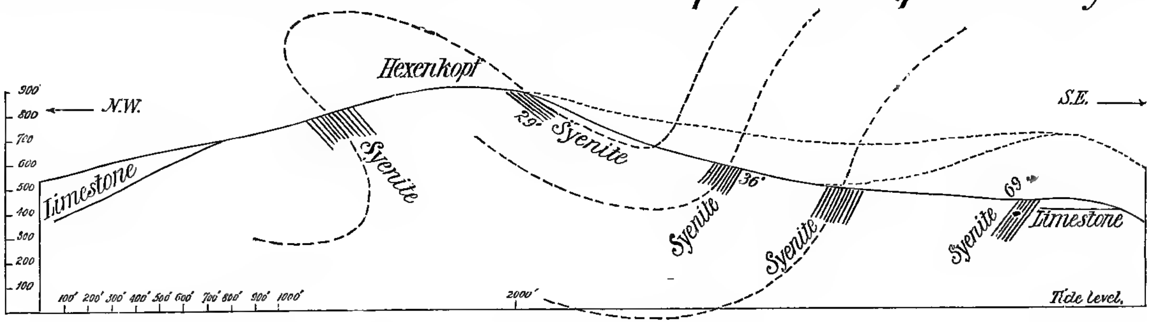
But down on the road, in the ravine, ½ mile east are three exposures, all N. W. 36°, 69° and 50°. Also on the summit a mile south of the Hexenkopf (720′ A. T.) one N. W. 49°. This group taken together would make the whole mountain between the two summits a *synclinal.*

But in the strike of the last (N. W. 49°) dip 1100 feet distant north-eastward, is an exposure S. E. 55° ; and 200 feet south of the N. W. 49° dip, is another S. E. 45°, which would make an *anticlinal* of the crest of this ridge.

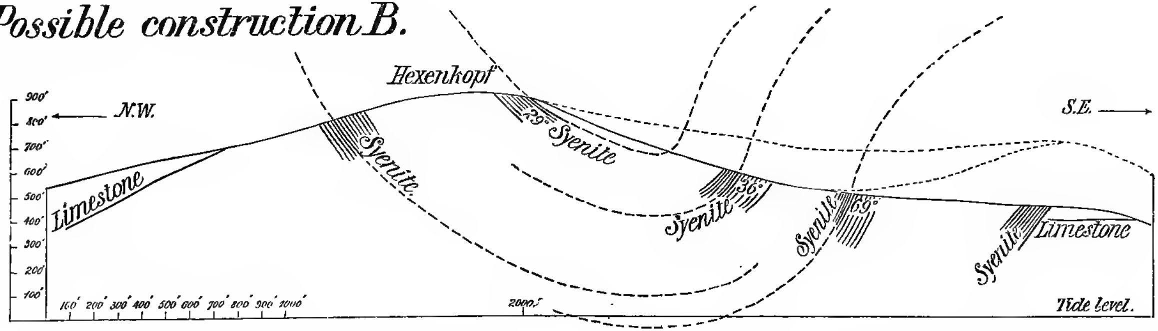
This last dip plunges the gneiss southward under the Uhlersberg synclinal limestones. But the N. W. 50° dip in the ravine above mentioned, only 150 feet from the edge of the limestone, plunges the gneiss not towards and under, but away from the limestone ; which again looks like a

*See the southeast sheet of the Six sheet map.

Possible construction A. across the Hexenkopf, Northampton County, Pa.



Possible construction B.



D3.

non-conformity of the limestone on the gneiss ; all the more because no Potsdam is here seen.

This will suffice to show the reader what great difficulties beset the study of the real structure of the syenitic gneiss ridges of the South mountain belt; how unsafe it is to describe them as simply so many anticlinals, and how impossible to assign to them the form of *overturned anticlinals.* Some of them are probably synclinal ; in some of them the dip is probably all one way. In order to bring this embarrassment distinctly before the readers eye two possible but opposite section constructions of the Hexenkopf are placed side by side on page 75.

The thickness of gneiss beds expressed by the three N. W. dips in the ravine east of the Hexenkopf is 1200′, upon a curved construction such as represented in the plate. But as the strike lines at all the exposures differ in direction it is possible to make a construction which will increase this thickness to 2000 feet.

The six dips at the river side a mile below the bend, above mentioned, show also 1200′ of gneiss rocks, upon a careful curve construction including them all ; but only 800′ considering the two southernmost dips on an overturned synclinal.

It is impossible to say how many hundreds or possibly thousands of feet of gneiss show themselves in the South mountains; but the frequent changes of dip from north to south, and the numerous synclinals of limestone, make it probable that only 1000′ or 2000′ of the Laurentian series come to the surface.

Whether these be the top members of the series or not is also uncertain ; because if the structure be nonconformable to the limestone, the edge of the limestone is no guide to the top rock of the gneiss ; and consequently the eroded ridges may present strata of any part of the Laurentian series.

Of course the syenite rocks underlie the limestone belt north of the Lehigh, as they do the Durham and Saucon valleys, and the stretch of limestone south of Easton. In fact we see *Morgan's hill* nosing down westward beneath

the limestone, a mile south of Glendon, before reaching the Lehigh, and its southern fork plunging beneath the limestone at the Lehigh at Freemansburg and Shimersville. The summit here is 710′ A. T. and in the three or four miles along the river eastward there are summits of 630′, 590′ and 670′ A.T. South of the river 1½ miles is another shorter line of summits, up to 680′ and 810′ A. T. Here the Potsdam sandstone, *under* the limestone, rides up on the slope of syenite, (see Mr. Prime's report further on.)

In like manner the great range south of the river opposite Bethlehem, rises from beneath the Saucon limestone, and brings up Potsdam sandstone with it.

But in the very heart of the limestone belt north of the Lehigh we see the syenite floor rising in ridges, and casting off the limestone strata both ways. These low ridges must be looked upon as parts of the syenite belt, and as *underground mountains*, the western continuations of the New Jersey highlands, *still covered with limestone.* Let the world last long enough, the gradual erosion of the surface of Northampton county will so lower the limestone hills around these ridges, that they will stand out in air like the South mountains; for they are now exactly like the Durham hills.

Outlying ridges in the limestone belt.

Chestnut hill just north of Easton is merely the sunken west end of Scott's mountain in New Jersey. It has a remarkably sharp and regular crest, steep sides and abrupt end at the river. Its highest point is 710′ A. T. (=550′ above the water;) falling westward to 500′ A. T.; cut through by Bushkill creek; and sinking beneath the limestone 6½ miles west of the river. It stays underground for a distance of 7¼ miles, and then rises as *Quaker hill* and *Pine top;* runs on in the same W. S. W. straight course 5¼ miles more; sinks again and is seen no more.

Quaker hill has two summits, 520′ and 600′ A. T. It is separated from Pine top by a small dry ravine 330′ A. T.

Pine top has two summits, 460′ and 500′, and is cut off from the west end of the ridge by the Manocacy valley 280′

A. T. The highest part of the west end of ridge, at the cross-roads is only 390′ A. T.

Another isolated range of syenite has been already mentioned. It rises from beneath the limestone 2 miles west of Bethlehem and runs along the north bank of the Lehigh 2½ miles to near Allentown, where it sinks beneath an anticlinal arch of Potsdam sandstone.

These mere crests of mountains sunk beneath the limestone formation, would become mountains 2000 or 3000 feet high were all the limestone strata between them and the Lehigh river dissolved away. They must not be looked upon as *sunken mountains* in any other sense of the term. They were never higher than they are now (except the little erosion which they have suffered since their uncovering), but on the contrary have ascended from an immense depth. Before the elevation and plication of Pennsylvania, these syenite strata lay buried beneath all the Palæozoic formations, including the coal measures; and consequently at a depth of 30,000 to 40,000 feet; consequently where the normal temperature must have been between 600° and 800° Farenheit; a heat which sufficiently accounts for their crystalization; and for the marbleization also of the limestone strata, the induration of the Hudson river states, and the partial metamorphism of the Oneida and Medina quartzites. The assistance of heat in effecting slaty cleavage will be alluded to in its proper place, under that head of this report.

The geology of Chestnut hill.

Chestnut hill north of Easton, is an outlying ridge of syenite, with a straight crest, and ought to show an anticlinal structure if the South mountains do; but it does not. Its rocks dip S. E. 31° at the Delaware, S. E. 59° on the summit half a mile west; S. E. 30° at the road north of the city; S. E. 43 on the crest, east side of the Bushkill; S. E. 41°, 100 feet down the south slope; S. E. 66°, descending the steep to the Bushkill; S. E. 48°, 40° and 38°, at the road along the east bank of the Bushkill in the gap; S. E. 56°, 41° and 40° on the west bank of the Bushkill in the

gap; S. E. 28° on the crest ½ mile west of the Bushkill gap, and S. E. 54° west of the road below the last dip.

The monoclinal south dipping structure of Chestnut ridge seems then to be completely established. Its rocks dip beneath the limestone border south of it, but away from the limestone border north of it. Yet the *limestone* at the north edge of the gneiss at the Bushkill gap *dips* N. 28°; at the bend of the road ½ mile west N. 12°, and at Sipe's, north of the west end of the gneiss N. 80° W. 37°.—The *Potsdam* only appears at its west end (Sipe's) sliding from off it at a dip S. 80° W. 26°.

Its monoclinal structure is also shown by the fact that a belt of magnesian strata (serpentine, &c.,) 200 feet wide borders it on the south side, but not on the north; and these magnesian rocks dip S. 20° E. 44° at the Bushkill gap, conformably with the underlying gneiss series to which they *probably* belong; but conformably also with the overlying limestone rocks (40°, 30°, 33°, 44°, 35°, 41°, 48°, 38°, 34°,) to which they may *possibly* belong.

The Chesnut hill syenite is in massive beds like all the South mountain gneiss; and the general south dip is disturbed in many places (as seen in the Delaware) by many contortions such as no doubt pervade also all the rocks of the South mountains.

The Weygatt is a syenite cliff overhanging the Delaware where the feldspar-quartz rock is cut by veins of epidote (a silicate of alumnia, with lime, or iron, or magnesia.)

The serpentine belt appears on the Delaware south of the Weygatt. Here it is yellow serpentine with calcite crystals, grey limestone and asbestos. Far up the south hill slope is a mass of semi-crystalline greenish grey augite, and pink calcite; tremolite crystals occur near by. Nephrite, bluish and pink, and containing small crystals of tremolite, abound in the serpentine just west of Wolf's old quarry. Just south of the nephrite is slaty, greenish and whitish talc, some of it compact, mixed with serpentine and pervaded with fibrous carbonate of lime.*

South of this band, is another of coarse syenite, with

*See Rogers, Geol. Penn., I, p. 94.

reddish feldspar, containing tourmaline and sphene. One of the beds at the river water-level has its joints filled with soft asbestos.

South flank of Chestnut hill.

On the south side of Chestnut hill gap on the Delaware, the *Potsdam* shows as both common white sandstone and vitreous sandstone.* Over it the limestones are changed into crystalline dolomite holding serpentine, &c.

In contact with a dyke of coarse granite near the south side of the gap, the slates, with bedding and dip still clearly perceptible, are changed into chlorite, mica and hornblende slates. In the coarser grits the original pebbles are visible.

Towards the north side of the gap, after passing a great thickness of massive, coarse, feldspathic granite, we come upon a massive bedded rock, apparently stratified, dipping steeply north. Just at the north end of the gap is a considerable talus of Potsdam sandstone. In the north-west flank of the hill the rock in place dips nearly vertically northward.

Near the center of the gap is a considerable mass of dolemite, serpentine marble and slate, which Mr. Rogers reports (p. 243) and explains by the hypothesis of a double anticlinal and included collapsed synclinal. He supposes also two eruptions of granite, altering the gneiss and other rocks.

Just west of the Easton-Wind gap road silvery mica once abounded; and scaly talc containing zircons. Near the reservoir spring is white and also greenish tabular tremolite, some of it minutely specked with graphite. In a meadow west of this has been found serpentine containing pink and white calcite, and irregular masses of tourmaline in crystalline serpentine. Augite crystals have been found.

Approaching the Bushkill the syenite is flanked by a large bed of tremolite rock holding grey tourmalines.

On the steep, facing the Bushkill (west bank), is beautiful dark green serpentine (streaked with calcite and asbestos)

* Rogers.

lying in solid beds several feet thick, regularly stratified overlying the syenite beds. Serpentine slates lie between the massive serpentine beds; and also micaceous beds.

North flank of Chestnut hill.

On the north side of Chestnut ridge no serpentine belt is represented on the Six sheet map, nor any reported by the geologists of the First Survey except at one point, which certainly requires careful consideration, as it must materially affect our views of the anticlinal structure of Chestnut hill.

At the north in Chestnut hill a road crosses it half a mile west of the Bushkill gap, and descends only 30 feet before it touches the edge of the limestone on the north side of the hill, at 360′ A. T. Descending 30 feet lower, the road rises again 30 feet and makes a turn west a house standing on a low hill top 100 feet above the creek which sweeps around it. This is in fact a sort of spur from Chestnut hill pointing north-east, with a little limestone valley to the south-east, between it and Chestnut hill.

This spur is colored limestone on the map. In this spur Prof. Rogers (Geol. Pa., I, p. 95) speaks of slates, asbestoid and talcose slates, near the creek; and west of this, higher up the hill, blue limestone in place close to the gneiss. "At the first of the above localities, the limestone in contact with the crystalline rocks forms only a tongue or point, running in from the westward, between the main ridge of Chestnut Hill and a smaller spur which runs out to the Bushkill a little above the new stone mill.* *This smaller ridge consists chiefly of serpentine and talcose rocks*, bounded at a short distance on the north by the blue limestone. Some of the talc contains cubic crystals of sulphuret of iron, and some of it is interspersed with fine green serpentine, in which crystals of zircon are said to have been found."

For a more detailed account of the formations in North-

*Published in 1858.

ampton county the reader is now referred to the following chapters, which embrace the reports of the assistant geologists who have studied the region: Mr. R. H. Sanders, Dr. H. M. Chance, Professor F. Prime, Jr., and Mr. E. V. D'Invilliers.

CHAPTER II.

The Slate region.

(By R. H. SANDERS.)

The following report covers all that part of the great valley which lies between the Delaware river and the Schuylkill river, and between the Blue or Kittatinny mountain on the north, and the edge of the limestone on the south; comprising the northern half of Northampton and Lehigh counties and the north-eastern quarter of Berks county; with an extreme length of 50 miles, and a maximum breadth of 13 miles.

It is an irregularly accidented low hill country, strongly contrasting with the limestone country which borders it on the south, both in the comparative number and ruggedness of its water-courses. This contrast appears upon the maps. The main streams flowing southward through the slate land into the limestone land have numerous branches in the slate and very few in the limestone; and, instead of low, gently swelling divides or level plains, sudden and sharp ascents and descents between the water beds and the uplands is the general rule; and mill sites are numerous.

There are, however, almost no well-defined ridges marking the outcrops of harder subdivisions of the great slate formation; so that it is difficult to separate the main belt into subordinate belts. The single exception to this is to be found in *Shochery ridge* in Lehigh county. Perhaps *Sandstone ridge* north of Hokendauqua may also be cited.

The whole mass is one formation, equivalent to the *Hudson River slate* formation of the New York Geological Survey, excepting that along the southern border, Mr. Prime

reports occasional traces of the *Utica black slate* formation immediately overlying the *Trenton limestone.*

This southern border of the slate district is everywhere a one-sided hill, or steep descent towards the limestone lands; and an accurate representation of this border ridge will be found upon the contour line maps accompanying this report, and the preceding Report D².

The whole formation is divisible into an upper and a lower mass, the upper being more massively bedded, and therefore supporting a somewhat more elevated country. Its uppermost beds constitute the southern slope of the Blue mountain.

The large and important roofing slate quarries are all in the lower subdivision of the formation, as is shown in Fig. 20.

The thickness of the whole slate formation cannot be got by actual measurement. I have surveyed in successive years the entire extent of the slate belt of the great Cumberland Valley, through Franklin, Cumberland, Dauphin, Lebanon, Berks, Lehigh and Northampton counties, *i. e.* from the Maryland State line to the New Jersey State line, and have found no place where an accurate continuous measurement of the beds from top to bottom can be obtained. Even an approximation to the total thickness is not easy. Natural exposures are almost entirely wanting. The only places where the beds can be seen are in railroad cuts, on wagon roads, and at open quarries. The valley slopes seldom reveal anything, and the upland never. Occasional low cliffs are exposed in the river banks.

The obstacle in the way of instrumental measurement and calculation, is the plicated condition of the belt, numerous rapid changes in the strength of dip, and numerous local anticlinal and synclinal rolls, some of them so sharp as to make it almost certain that some of the high south dips are *north dips overturned.*

Although in New Jersey a thickness of only 3000 feet is assigned to the whole formation, the locality named being at the Delaware Water Gap, my measurements along the west bank of river make it more than 5,000′.

Upper beds, mostly more than one foot thick, measured from Williams' old quarry up to the *Oneida Conglomerate* in the Delaware Water Gap,	1540′
Lower beds, mostly of beds less than one foot thick, measured from opposite Belvedere up the river to R. Sohook's, ...	3700′
Total, ...	5240′

The top of the lower mass, at Schock's, could not be accurately located, and the total of 5,240′ is more likely an understatement than an exaggeration of the actual thickness of the formation as a whole.

Mr. Chance's independent measurement at the Water Gap places the two quarry beds at 1,000′ and 2,350′ respectively beneath the *Oneida conglomerate*; and his estimate of the whole thickness of the slate formation is as large as mine.

In Lebanon county, in Monroe county I got 6,000′ as the probably total thickness.*

These 5 or 6,000 feet of rocks consist of beds of slate varying in thickness from $\frac{1}{100}$ of an inch up to at least thirty feet, being nearly all of a dark grey, bluish-black color, fine and coarse grained, with occasional beds of sandstone which are not persistent.

The descriptions of localities I have grouped, in separate townships, beginning at the north-east on the Delaware river, and ending at the Schuylkill.

Each locality is numbered, and its number placed upon the map, with a line to represent the direction of the strike of the rocks, and a barb to show the direction and strength of dip; the dip being always *away from* the strike line, and the barb being at right angles to it when the dip is 90°, and closing back upon it as the dip diminishes; so that *a line without a barb* represents *horizontality.*

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*Prof. H. D. Rogers gives the *Utica slate* (his *Matinal slate*) at Martin's creek on the Delaware, as 300′, but says of the rest of the formation that "along the Kittatinny valley it is not anywhere susceptible of accurate measurement." (Geol. Penn. 1858, Vol. I, page 125.)

The formation thins away westward; for, in Huntingdon county, at Rockhill gap, Mr. Ashburner's measurements made it only 1,870′; and in the gaps of Blair county my measurements gave only 900′. (See reports F and T.)

A. *Notes of Quarries, &c., in Northampton.*

Upper Mount Bethel township.

1. Washington Brown's Quarry.—The quarry is on the slope of the mountain overlooking the Delaware. The quarry has only recently been opened. It is 75×75×40 feet, and is 600 feet below the Oneida sandstone. The slates dip 25° N. 40° W. cleavage flat. The slates have a good color and are smooth, only a few have been made.

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2. John Morrison's Quarry.—The quarry is at the foot of the steep slope of the mountain, between 800 and 900 feet below the Oneida sandstone. The quarry was opened in 1877. It is 150×100 feet square, now full of water, probably about 50 feet deep. There is from five to fifteen feet of *Drift* on top of the slates. The slates are decomposed under the drift. Slates dip 20°, N. 40° W. Cleavage flat. The beds are four feet and under in thickness.

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3. J. W. Williams' Quarry is half a mile northwest of Slateford. The quarry is 150×150×100 feet, with from 30 to 50 feet of *Drift* on top, someof the bowlders in the drift are 2 feet in diameter. The thickest bed is 4 feet. The slate dips 20°, N. 10° W. Cleavage 2°, S. 10° E. The drainage cut shows 150 feet of slate below the quarry. At the factory the *ribbon slate* is seen in the bed of the creek. They are about fifty feet below the quarry. The quarry is not being worked.

This was the first slate quarry opened in Pennsylvania viz: by Mr. Williams, about the year 1812. It is described in Prof. H. D. Rogers' Geology of Pennsylvania, Vol. I, p. 248, as follows; but the *fault* is not now visible, being buried under water and dêbris:

"The quarry at present (*i. e.* previous to 1858) is in the form of a beautiful amphitheater or circle of cliffs, about 100 feet in diameter, and at least 60 or 70 feet high.

"The strata, fine bluish slate with ribbons of bedding, dip about 30° to N. 30° W., with remarkable regularity. In all the portions below a certain plane, apparently that

of a slip or a *fault*, the cleavage is very nearly horizontal; but immediately above that plane, the cleavage planes of the first course curve down steeper and steeper towards the S. E. or S. 45 E. and in all the still higher ones the tendency is to a S. E. dip, but only very gently, except in the northwestern parts, where it is more obvious. . . . . . .

"The texture of this slate, in the absence of any defining fossils, suggests that it may belong to the Utica Slate Formation, and it is quite conceivable that an axis at this distance from the outcrop of the Levant sandstone of the Kittatinny mountain may lift the Matinal slates to day, but this needs confirmation. The true stratification of the rock is only detected by the difference in color caused by numerous very thin layers, from a few lines to an inch or two in thickness, traversing the rock in bands parallel to each other, and at various distances not generally exceeding two feet. These ribbons denote the direction of the dip of the strata, being seams of somewhat different composition from the rest of the mass. Between each two of these ribbons the layer of slate is homogeneous, or of uniform texture and composition; but a difference in the quality of the slate on the two sides of one of these thin layers is quite common.

"When we examine a new surface of the slate, the usual and permanent color of which is dark bluish-gray, the hue of these ribbons is nearly black; but on exposure to the atmosphere they show after some time signs of spontaneous decomposition, and display a whitish efflorescence, which indicates that this part of the slate contains the sulphuret of iron. These ribbons are, therefore, carefully excluded from the slate when they undergo the operations of cleaving and trimming in their preparation for the market.

"At one place in the quarry the dip of the strata, as indicated by that of the ribbons, is towards the W. N. and W. at an angle of about 30°. In the same part of the quarry the dip of the cleavage planes, or in other words, of the slates, is towards the south at an angle of nearly 50°. Here, however, is the same dislocation or *fault* traversing the quarry as in the spot first described.

"This *fault* is a slide of one part of the stratum upon the

other, and is from six to twelve inches wide, being filled with white calcareous spar and fragments of slate. The rock below it has not only a different actual dip from the portion of the stratum above it, just alluded to, and a different direction also in the cleavage of the slates, but a different quality in these slates themselves; those beneath being much superior to those over the dislocation. From this lower part of the quarry, nearly all the roofing and writing slates are derived. The best school slates are got from belts that lie directly beneath the sparry seam or fault.

"The direction of the *cleavage planes* in this portion of the mass is nearly horizontal, while the planes of stratification dip towards the N. W., but at a very moderate angle.

"The difference of direction of the cleavage planes above and below the fault, renders it possible that the dislocation and slide in the stratum took place after the mass had acquired this remarkable tendency to cleave in a direction oblique to the stratification; for had the cleavage originated subsequently to the disruption of the rock, we ought to find it maintaining the same direction, and observing the same features on both sides of the fault. These facts concerning the change in the quality and position of the slates caused by the dislocation, indicate how numerous and minute the circumstances are which must be attended to by those who enter on the business of quarrying this rock."

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4. Emory Pipher quarry, a few hundred yards west and slightly below Morrison's quarry, is an abandoned quarry, irregular in shape, covering about 200×100 feet. From the appearance of the quarry it has not been worked for some years. The beds seen are small, but only part of the face could be seen as most of the sides have fallen in. The dip in the south and central part of the quarry is flat; at the north edge the slate dips 20°, N. 40° W.; the cleavage 20° south. At the school-house on the road passing this quarry a thin slaty sandstone shows.

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5. Snowdon quarry. (See Fig. 1.)—This quarry, owned by H. P. Jones, is 500 yards northwest of Williams quarry.

The quarry is 150×150×40 feet. There is 15 feet of drift on top. Two of the largest beds are 14 and 12 feet thick, the cleavage is 26° south. At the north side of the quarry there is a fault showing, probably the same fault as described by Prof. Rogers in the Williams quarry. The bed south of the fault dips 40° north.

They make about 150 squares a month. The quarry is worked by one spar derrick, and run by horse power. It was started in 1870.

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6. The quarry, (Fig. 2,) worked by William Mannus of Scranton, on Peter Fry's farm is not now worked. It is 300×150 feet and full of water.

There are no large beds to be seen in the quarry.

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7. L. Grone's farm, 1½ miles north-east of East Bangor. Here is a small abandoned quarry 50×50×15 feet. The slates dip 20°, N. 40° W., with a flat cleavage. The largest bed is 2 feet thick. The cleavage does not look good, as it is twisted.

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8. J. Oyer's farm, 1½ miles north of East Bangor. Here is a quarry 100×100 feet full of water. The beds that are above the water are 3 feet thick and less. There is 10 feet of *Drift* on top of the slate. Dip 10°, N. 40° W., cleavage 20°, S. 20° W.

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9. Opposite Belvedere. The contact of the slates and limestones on the Delaware river shows by a high ridge. The dip is 70°, S. 20° E. and the cleavage 25°, S. 20° E. The same dip shows for three quarters of a mile up the river. The slates are thin bedded, compacted together, making solid beds, in some cases 10 feet thick, between loose ribbons. From the river road up north until the road leading from Centreville to Porterville is reached, nothing but ribbon slates show.

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10. Centreville. On the road half a mile east of Centreville, one foot of sandstone shows with a dip 25° south.

11. C. Wolf's farm on Martin's creek half a mile east of the township line. Here is a small excavation which shows the slate dipping 15°, N. 40° E. The cleavage dip is 60°, S. 40° E. The slates are ribbon slates.

Within a mile and a half of Bangor there are 15 quarries. I will start at the most easterly one and go west with my description.

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12. East Bangor quarry, No. 3.—Owned by Bry & Short. The quarry is on the north side of the railroad, east of the wagon road leading north from East Bangor. It is 150×50×50 feet. The dip of the slate is 5°, S. 40° W. Cleavage 20°, S. 10° W. The beds are rather small. The quarry is not being worked.

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13. Old East Bangor quarry.—Owned by Fisler & McKean. This quarry is across the road from East Bangor No. 1. It is 250×150×50 feet, with water in the bottom. The dip is flat, the cleavage is 20°, S. 10° W. When the quarry was visited they were not making slate, but stripping and putting in new hoisting machinery. The largest bed showing was 3 feet thick. The slate made looked good.

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14. East Bangor, No. 2.—Bry & Short's quarry, 300 yards west of the old East Bangor quarry, is 200×150×60 feet, with a dip of 10°, N. Cleavage 20°, south. The largest bed is four feet thick. They were not making slate but were stripping new ground. The quarry is worked by two cable derricks, run by one double-cylinder engine.

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15. East Bangor No. 1.—Bry & Short's quarry between East Bangor No. 2 and the railroad, is 250×200×100 feet. Dip is 20°, N. 20° W. Cleavage 20°, S. 20° E. The beds are 16, 10 and 11 feet in length along the cleavage. The quarry is worked by one cable derrick. There are 5 shanties in operation.

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16. Star Quarry.—Major Aims', 500 feet west of the

East Bangor No. 2, is 200×200×50 feet. Cleavage 20°, south. It is worked by three cable derricks run by one engine. They also have one spar derrick worked by horse power. There are 10 shanties running and also 3 small circular saws on school slates. There is an old quarry (not being worked) just south of this, on the same beds as the East Bangor No. 1.

Washington township.

Coton Aim's quarry, is close to the township line, on the north side of the creek, it is 100×50×40 feet, with from 10 to 25 feet of *Drift* on top. Dip 25°, N. 40° W. Cleavage 20°, S. 4° E. The beds are all small. There are three shanties in operation. Some of the slates made are made from single beds, while others have two or more beds in them. The slates made from the ribbon slate are mostly bent; others are good except a few which are slightly bent.

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17. Bangor Central quarry, one quarter of a mile west of the township line on the north side of the creek, is a cut 200×100×40 feet and 40 feet deep at the deepest place. The dip is 25°, N. 40° W. Cleavage 10°, S. 40° E. They make slate out of single beds and from two or more beds; some of them are bent but very slightly. The quarry is worked as an open cut on the side of the hill. The beds showing are all small.

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18. Bangor Old quarry, 500 feet west of the Bangor Central, is a side hill cut 50 feet deep at the face, with from 15 to 30 feet of *gravel* on the top. The dip is 25°, N. 40° E. Cleavage 15°, S. 40° W. The slates on the bank are made from single beds and from two or more beds. Some of them are much bent.

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19. Powell's quarry.—On the south side of the railroad, three quarters of a mile east of Bangor, is a side hill cut, 300 feet long, by from 50 to 100 feet broad and 80 feet deep

at the base. The dip is 25°, N. 40° W. cleavage 15°, S. 40° E. There is from 5 to 15 feet of *Drift* on top. The largest bed is 4 feet thick. The slates on the dumps are made from one or more beds. All those with two beds in them were bent, some few of the others were also bent.

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20. Bangor Valley quarry.—A few hundred feet west of Powell's quarry is an irregular shaped cut 200×150×50 feet, the dip is 20°, N. 50° W. cleavage 10°, S. 50° E. There is from 5 to 10 feet of *Drift* on top. The largest bed is 3 feet thick. The quarry is on top of the *Bangor axis* and the slates are above the Bangor slates. The quarry is not being worked.

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21. Bangor quarry, (Fig. 3.)—One quarter of a mile east of Bangor. Is 600×400×130 feet. A *synclinal axis* shows passing through the center of it, about 70 feet below the surface; the plane of the axis dips 5° to the north, the cleavage also dips 5° north.

There is 30 feet of *Drift* on top of the south side of the quarry. The largest bed is 9′ 6″ thick. The *synclinal axis* pitches to the west, being the same synclinal that shows in the Washington quarry and the Bangor Union. The slate in the north end of the quarry would come to the surface at the railroad, on a line between the Washington and Bangor Union quarries. The slate on the south side of the quarry probably shows in the Washington quarry. There are 60 men engaged in quarrying, besides the drivers engineers and splitters. The quarry is worked by horses and carts and also by three cable derricks run by separate engines. There are 42 shanties in operation.

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22. Washington Quarry, (Fig. 4,) owned by Fulmer & Wagner, just west of the Bangor quarry, is 150×100 feet, reported 70 feet deep, but full of water. There is 20 feet of *Drift* on top. Cleavage 12°, N. 30 W.

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23. Bangor Union quarry is some 250×250×130 feet deep at the deepest place, with from 10 to 20 feet of *Drift* on the

surface, the largest bed is 4 feet thick. The *synclinal axis* which shows in the Bangor quarry also shows in this one, but the plain of the axis dips slightly to the south instead of the north as in the Bangor. The quarry is worked by 5 cable derricks, which supply material to 20 shanties. The derricks are run by one engine, which, working a line of shafting, connects with the cable derricks by conical friction wheels. The quarry is running on roofing and school slates. Those slates made just below the turn of the axis are bent; the others are good. The beds in the quarry are tight and some of the slates are made across the beds.

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24. North Bangor No. 1.—The south-east corner of the quarry is 200 feet west of the north-west corner of the Bangor Union. It is 200×200×40 feet at the deepest place. There is 20 feet of *Drift*, and they make slate one foot below it. The cleavage is 10°, S. 30° E. The dip is 45°, S. 30° E. The two largest beds are 4 feet thick. There is a bed measuring 10 feet along the cleavage; at the south end of the quarry this 10 foot bed has two feet of rock on the top of it, making only 8 feet of it workable. The beds show all the way across the floor of the quarry; all of them are under 4 feet in thickness.

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25. North Bangor No. 2 quarry, a few hundred feet north of No. 1, is 150×100 feet and about 40 feet deep, and is full of water. The dip is 35°, S. 30° E., cleavage 15°, S. 30° E. The beds that show are mostly small, under 4 feet in thickness. I was told there were two measuring 12 feet in the quarry, but could not see them as it was full of water.

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26. North Bangor No. 3 quarry (Fig. 5.), two hundred feet north of No. 2, is a side hill cut 150×200×100 feet at the face. Is of irregular shape and is worked at the center of the *synclinal axis*, the plain of the axis dips 15°, S. 30° E. The cleavage dips the same.

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27. Jacob G. Pyster's quarry one and a half miles S. E. of Bangor, is a small opening 50×50×20 feet. The cleavage

is 30°, S. 30° E. The dip could not be determined, the quarry not being worked, but there are a few rough ribbon slates on the dump.

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28. Two miles S. E. of Bangor, on the east side of Martin's creek, on P. Pysher's farm, there is a small cut 50×30 ×30 feet, with the slates showing a dip of 10° N. and the cleavage 30° S.; the slates all thin bedded, ribbon slates.

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29. True Blue slate quarry (Fig. 6), on Martin's creek one mile east of Factoryville, an open cut of irregular shape, averaging about 150×150×80 feet deep. At the face the structure is shown as above. In the cut the cleavage is 25° S. parallel to the plane of the two axes. At the bottom of the cut *a quartz vein* shows one foot thick dipping 25° S. This vein spoils the cleavage for a short distance on each side of it. On the south-east corner of the quarry a few small *quartz veins* show. The slates are all thin bedded; they have a good metalic ring, but those that have been exposed on the dump show signs of bleaching. The quarry is not being worked.

Lower Mt. Bethel township.

30. On Little Martin's Creek, half a mile above the school-house, ribbon slates show dipping 70° N. with a cleavage of 25° south.

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31. A quarter of a mile below the school-house ribbon slates show with a flat dip and cleavage of 25°, S. 10° E.

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32. In the bottom of a small hollow half a mile north-west of Martin's Creek Post Office, there is a small abandoned quarry of ribbon slate. Dip 45°, N. 20° W. Cleavage S. 20° E.

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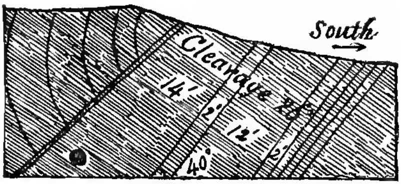
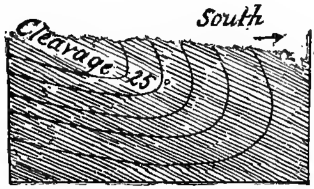
33. Just about the mouth of Martin's creek the contact of the slates and limestones shows. The slates for half a mile up the creek are seen dipping slightly towards the

1. Snowdon Quarry, No. 5

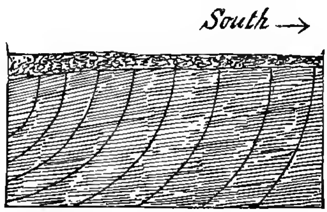


2. W. Mannus' Quarry, No 6.

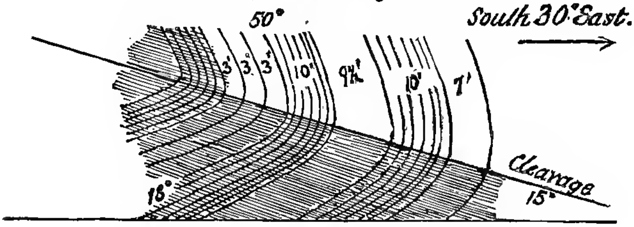


3. Bangor Quarry, No. 21.

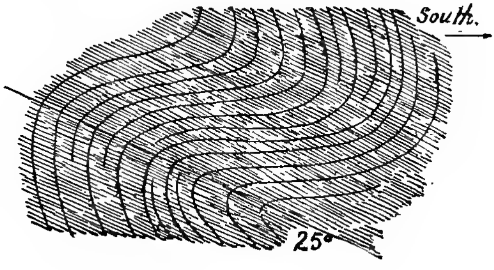
4. Washington Quarry, No 22.



5. North Bangor Quarry, No. 26



True Blue Slate Quarry, No. 29.



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north, and are very much contorted. The cleavage is flat, the beds are small but not ribbon slate.

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34. Just east of where the road from Martin's creek crosses Mud run, vertical black slates show with an *horizontal cleavage.* The largest bed is two feet thick.

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35. On the road leading down Mud run between Hutchinson & Kahler's an *anticlinal* shows in the slates. The slates are ribbon slates. In the same cut two *veins of quartz* show dipping steeply to the south.

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36. Just west of Hutchinson's ribbon slates show dipping N. 20° W. Cleavage 40°, S. 20° E.

Forks township.

The contact of II and III enters the township a few hundred yards south of its north-east corner, and passes through the township in a south-westerly direction, crossing Bushkill creek into Palmer township west of the Lutheran church at Churchville. In Palmer township the junction line is not well shown. The area covered by slates is a strip across the northern portion of the township half a mile wide.

Plainfield township.

37. Hulls' quarry, owned by A. & O. T. Hull, one mile north-east of Pen Argyl, is 250×150×80 feet. There is 15 feet of loose slate on the top. The dip on the surface is 68°, S. 10° E. but is steeper in the lower part of the quarry. The cleavage is 15°, S. 10° E. The two largest beds are 10 feet and 7 feet thick. They work other beds in the quarry but they are smaller in size. Blocks come out of the quarry in good even pieces and split and sculp well. From the relative size of the dump and quarry I should say there was not as much waste as in the average run of the quarries. The quarry is worked by two cable derricks and has 5 shanties in operation.

38. Pennsylvania quarry, at the north end of Pen Argyl, is 250×200 feet and full of water. At the north end the dip is 55°, N. 30° W. and gradually flattens towards the south side. The cleavage is 25°, S. 30° E. Seventy feet from the north end a 20 foot bed shows. Some distance below this there is a 6 foot bed. The rest of the beds showing above water are smaller. Most of the ribbons are tight.

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39. Jory quarry, owned by N. A. Jory & Co., is 400×200×80 feet. It is worked in the center of a *synclinal* axis. The dip of the rocks is slight in the center of the axis. The plain of the axis is *vertical*, while the cleavage is *horizontal*.

☞—This is the only quarry in which the cleavage can be seen at right angles, or any considerable angle to the plain of the axis. The beds worked are not large, but the cleavage making such a slight angle with the bedding large blocks can be taken out. They were making about 25 squares a day with 4 shanties at the time of visiting the quarry. There are two spar derricks worked by horse power.

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40. Jackson's quarry is 300×200 by about 100 feet deep. It is worked by two cable derricks, run by two double-cylinder engines. There are 4 shanties in operation and they average about 4 squares a day to a shanty. The slates come out in good sized blocks, some of them 20 feet long. They split and sculp well and fracture rather well.

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41. Robinson quarry, owned by Stephen & Jackson, is 400×200×80 feet. Dip 28° south. Cleavage flat. The beds are 25, 16 and 12 feet long along the cleavage. The quarry is worked by one cable derrick and several spar derricks, run by horse power. The cable derrick is run by a 35 horse power engine. There are 16 shanties in operation.

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42. West Washington quarry.—Fulmer and Jackson, is 150×75 feet and 50 feet deep in the deepest place. There is 25 feet of loose material on top. It is on the same beds as

the Robinson and the Jackson quarries. The best bed in the quarry is *the gray bed*, which is also worked in the Jackson. The following is the section measured along the cleavage. The dip is 48° south, and the *cleavage is flat*. Commencing on the top at the south end there is one bed 10 feet thick, 6 beds in 2 feet, there is a 2′, 3″, and a 7″ bed and 1′ 8″, 2′, 3″, 1′ 6″, 1′ 3″, 7″, 1′ 6″, 10″, 9″, 1′ 7″, 2,″ 1′ 10″, 9″, 15′ 6″, 6′, 3′, 3 beds in 6″, 3′ 7″, 6″, 2′, 9″, 1′ 3″, 4″, 1′, 2″, 11″, 3″, 1′ 1″, 1′ 5″, 6″, 10′ 2″ *the gray bed*, 30 feet of beds 2 feet and under in thickness, 4′. The 10 foot bed, at the top of the quarry has 2 feet of rock on top. It is a dark fine-grained sandstone. The gray bed has also rock on top of it.

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43. H. Young's farm 1¼ miles west of Blue Mountain Post Office. Here a small cut has been made in the side of the hill showing slate beds, the largest of which is 2 feet thick. The slate dips 15°, N. 20° W. The cleavage is 15°, S. 20° E. The cut is not into the solid slate.

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44. Delabole quarry at the eastern end of the township one mile west of Factoryville. It is 150×100 feet full of water. The dip is 80°, S. 30° E. cleavage 25°, S. 30° E. The quarry is all in thin bedded slates. The beds are large between the loose ribbons. There are a few slates left on the dump which show the cleavage to be slightly bent.

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45. Three-quarters of a mile west of the Delabole quarry thin bedded slates show, dipping 50° north. Cleavage 10° south.

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46. Pine Grove quarry.—Edleman & Co., is 200×159×130 feet deep. Dip 60° to the north. Cleavage flat. The slates are all thin bedded. They make besides roofing slate, flagging and fence posts.

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47. White Oak quarry.—T. Reed & Co , is 150×100×100 feet. Dip 20° N. Cleavage 10°, S. 45° W. The joints are vertical and in one part of the quarry it is 80 feet from joint

to joint. The slates are all thin bedded. For 300 feet north of the quarry the dip is the same. They average about 3,000 squares of slate a year.

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48. Samuel Seems quarry, one mile north by east of Belfast, is 200×200×80 feet. Dip 20° to the north. Cleavage *flat* or slightly to the west. The slates are all thin bedded. The largest bed is 30 feet between loose ribbons, the other beds that are worked are 16, 12 and four feet between loose ribbons. They make about 4800 squares a year. They also make flagging and fence posts. The quarry is worked by two cable derricks run by one engine.

---

49. Young, Duck & Co.'s quarry, one mile west of Kessler's Post Office, has been abandoned and is full of water. Dip 20° north. Cleavage *flat.* The slates are all thin bedded. From the amount of material on the dump I should say the quarry was about 25 feet deep.

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50. James Deck's abandoned quarry, 100×100 feet, is full of water. Dip is 15° north. Cleavage *flat.* The slates are all thin bedded.

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51. Two miles north-east of Kessler's Post Office, thin bedded slates show dipping 20° north. Clearage 40° south.

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52. Davidson's quarry, one mile south-west of Kessler's Post Office, is 150×100 feet, full of water. From the size of the dump I should say it was about 50 feet deep. It is abandoned and nothing left on the ground. The dip is 60°, N. 20° W. Cleavage 20°, S. 20° E. The slates are all thin bedded.

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53. Belfast quarry, half a mile south of Davidson's Quarry, is 150×75 feet and is full of water. There is 10 feet of stripping. The slates are all thin bedded. Dip 20°, N. 20° W. Cleavage 20°, S. 20° E.

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54. Half a mile south of the Belfast quarry, thin bedded

slates outcrop dipping 20° to the north, with a *flat* cleavage. 300 yards further south the thin bedded slates dip 60° to the north with a *flat* cleavage.

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56. At the school-house on the Pike just north of Belfast thin bedded slates show dipping 70° N. The cleavage about 15° south.

Bushkill township.

57. On M. Train's farm south of his house there is a shaft sunk for slates, 15 feet deep. The dip is doubtful but looks 50° S. Cleavage is 50° S. The shaft just enters the solid slate.

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58. Just west of Jacobsburg a thin bedded slate shows with a *flat* dip, and cleavage of 30° south.

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59. One quarter of a mile south of Jacobsburg the cleavage is 10° south.

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60. Hughes Bros. quarry.—Three quarters of a mile S. E. of Jacobsburg, is 100×150×60 feet. The average dip is 70° to the north and the cleavage is 20° south. The slates are all thin bedded, the longest distance between loose ribbons is 25 feet. 25 feet from the top of the quarry a *fault* shows dipping 20° to the south; it has moved the slate on top 3 feet to the south. They make about 1500 squares a year, and have made as high as 8 squares a day to a splitter, but 4 a day is a good average.

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61. Where the Bushkill creek leaves the township the thin bedded slates show with a *vertical* dip and *flat* cleavage.

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62. Henry's quarry is 150×200×70 feet. Dip is 20°, S. 50° E. Cleavage 13°, S. 40° E. The slates are thin bedded, the joints being vertical and running in different directions, the main joints are parallel to the strike. Some few *quartz*

veins show at the face of the quarry. The color of the different beds of slate is almost identical. The planes of loose cleavage are from 5 to 7 to 12 feet apart. They make about 3 squares a day to a splitter. The quarry is worked by two cable derricks, run by one engine. They make about 1800 squares a year.

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63. One quarter of a mile north of Mill Grove thin bedded slates show, dipping 70° to the south, and the cleavage is 15° south.

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64. One mile west of Mill Grove thin bedded slates outcrop, with a dip of 45° to the north.

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65. St. Nicholas quarry.—James Titas. On the township line 1½ miles west of Clearfield, 100×100×30 feet. Dip 15°, S. 40° E. Cleavage 55°, S. 40° E. One bed shows 10 feet thick, nothing else can be seen as the quarry is full of water.

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66. Douglass slate quarry.—On the north side of Bushkill creek west of Douglasville, is 300×150 feet and full of water. The water is up so high that neither the dip nor cleavage can be made out. The slates are all thin bedded, some of them on the dump have bleached more or less and some of the layers have iron pyrites in them.

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67. Nearly two miles west of Cherry Hill thin-bedded slates show dipping 90°.

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68. One mile northwest of Cherry Hill thin bedded slates show dipping 45° to the north.

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69. 1½ miles west of Cherry Hill in front of J. Heyer's house there are two small openings 50×75 feet and 20×20 feet. The slates are thin bedded and on the dump have bleached and rusted badly.

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70. A few hundred yards further down the run there is

an abandoned quarry 100×100 feet full of water, probably about 40 feet deep. The dip is 35° S., 40° E. and the cleavage 15°, S. 40° E. The slates are all thin bedded. Those on the dump have bleached.

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71. Daniel's quarry is abandoned and full of water, 250×150 feet, probably about 40 feet deep. The slates are thin bedded with a flat dip and cleavage of 20° S. Some of the slates on the pile have about 10 beds in them. There are about 50 squares on the pile, most of them have iron pyrites in them at the junction of the ribbons; the slates on the end of the pile have changed color. Some of them have also thin veins of quartz in them. On the east side of the creek 100 feet north of the Daniel's quarry, the thin bedded slates are seen turning to the north, the dip being 20° north. The cleavage is 20° south. 500 feet further north the dip is 20° to the east; 50 feet further north it is 10° north. 800 feet north of this there is a small abandoned cut 60×60 feet showing the slates flat.

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72. Half a mile north of Daniel's quarry a small opening 10 feet deep in thin-bedded slates shows, with a dip of 10° to the south and a cleavage of 15° south.

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73. Half a mile north of the above there is another abandoned quarry 50×75 feet, full of water. The slates are all thin bedded, bleached and iron stained The dip is flat and cleavage 20° south.

Upper Nazareth township.

74. At the north end of the borough of Nazareth the slates are flat and rolling.

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75. One mile west of Nazareth on the Bath road, black slates show, with a horizontal dip. A high slate ridge shows 1,000 feet north of the road, but the slates extend half a mile south.

Moore township.

76. Daniel Beer's quarry.—On the east side of the township half a mile south of the railroad, is 150×100 feet, full of water. It is on the same beds as the St. Nicholas quarry. There is nothing to be seen. The dip is 10°, S. 40° E. Cleavage 65°, S. 40° E.

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79. Chapman quarry is 500×300×130 feet. It has 6 cable derricks, run by independent engines. There are 30 shanties in operation. The splitters make from 2 to 6 squares a day, averaging about 4. The hoisting apparatus is very complete. They hoist a stone up 150 feet vertical and 300 horizontal in about 2 minutes, the stones probably weighing about 2 tons. There is a large factory for making and planing slabs and other sawed material. It has 3 diamond saws, 4 planers, 1 jig-saw and 1 smoothing table. The diamond saws cut by a reciprocating motion, cutting through slate at the rate of an inch in 5 minutes. They make about 50 strokes a minute. The slates are all thin bedded. They split well and are tough. The blocks come out of the quarry in large even pieces, some of them 20 feet long. They sculp and fracture well.

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80. A few hundred yards east of Chapman's there is an abandoned quarry 250×250 feet, full of water. Could not get dip or cleavage.

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81. East of Chapman's and across the creek there is another small opening 50×50 feet, full of water. Cleavage is 20°, S. 20° E. The dips could not be seen. The slates are thin bedded.

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82. Empire Quarry, on the Manocacy creek one mile east of Chapman's is not worked. 100×100 feet, full of water, probably 50 feet deep. Could not get the dip. It is probably vertical. The cleavage is 10° south. The slates are thin bedded. There is some iron pyrites showing in some of them. There are also a few small quartz veins running through the slates.

83. Richard Moser's quarry, 300 yards up the creek from the Empire, is 200×150 feet and full of water. The cleavage is 20° south. The dip could not be seen. The slates are thin bedded. They weather to a slightly different color, and some show iron pyrites.

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84. Mauch Chunk Quarry, at Chapman's Station, is 200×150 feet, full of water. Dip vertical. Cleavage 22°, S. 40° E. The slates are thin bedded.

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85. Bethlehem Quarry is 200×150×80 feet. The dip on the surface is vertical, then dips to the south a short distance and again becomes vertical. Cleavage is 10° south. The slates are all thin bedded. The distances between the loose ribbons along the cleavage of the workable beds are 7′, 7′, 3½′, 9′, 3′, and 3′. The quarry has one cable derrick run by a 15 horse-power oscillating engine. There are six shanties in operation. On the south side of the quarry they had to go down 60 feet before getting to good slate. On the north they went down only 20 feet. There is a *quartz vein* dipping to the south through the quarry 20 feet from the surface on the north side and 60 feet on the south. The slate above the vein has not a good cleavage.

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87. An abandoned quarry west of the last named and 300 feet on the strike from it. The cleavage dips 10° to the S. 10° E. Joints vertical. It is two hundred feet square. A *quartz vein* shows in this quarry the same as in the Bethlehem. 200 feet north of this there is another abandoned quarry 100×100 feet, full of water, but is not deeper than 50 feet.

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88. Thomas Ryan's Slate Quarry is 100×50×40 feet. The slates are thin bedded, joints vertical, cleavage horizontal, dip towards the south averaging about 60°. Some few slates have iron pyrites in them.

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89. Jacob Flinn's abandoned quarry, 1000 feet northwest of Ryan's quarry, is 100×40 by about 30 feet; dips 30°

to the north. Cleavage flat. I was told the reason the quarry was abandoned was that the slates were twisted. There are no slates left on the dump.

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90. A small abandoned quarry 1000 feet north of Chapman's 60×60 feet and full of water. Dip vertical. Cleavage S. 10° E. The slates are all thin bedded. 400 feet west of this there is another small abandoned quarry 100×40 feet full of water, with a vertical dip and cleavage of 10°, S. 20° E.

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91. An abandoned quarry, one mile west of Chapman's, 100×50 feet, full of water. Nothing to be seen except that the slates are thin bedded.

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92. Helman's quarry, 1½ miles south-west of Chapman's, dip 45° south ; cleavage flat ; joints are vertical. The slates are thin bedded. Those on the dump are bleached and iron stained and look poor. The quarry is 100×100 feet, full of water, probably 40 feet deep.

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93. McKees Quarry is 600 feet north of Helman's. The slates dip 22°, S. 25° E. Cleavage 15°, S. 25° E. The joints are vertical, running east and west and north and south. The slates are thin bedded. The quarry is abandoned and is 100×100 feet, and full of water, probably 60 or 70 feet deep.

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94. On the ridge a mile east of the Emanuel church, loose thin bedded *sandstone* covers the surface of the ground.

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95. 300 yards north of Emanuel church the slate dips 90° to the north with a cleavage of 45° south.

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96. Northampton Slate Quarry, one mile south-west of Chapman's. There are here two abandoned slate quarries, full of water. The southern one is 150×150 feet, the one on the north is about the same size; they are separated by about 25 feet of slate ; in the south one the dip cannot be seen ; on the west side of this opening there is 25 feet of

loose slate; 15 feet from the top there is a heavy *vein of quartz* dipping slightly to the south; the cleavage is 20°, S. 40° E. The slates are all thin bedded; those left on the dump appear very rough and thick; some of them have iron pyrites in them, and they have changed color.

---

97. An abandoned quarry, (Fig. 7,) half a mile south of Chapman's, 150 feet square, full of water. The slates are thin bedded with a vertical dip The horizontal section in the figure shows the contortions in the strike of the rock at the north-west corner of the quarry.

East Allen township.

The contact of slate and limestone enters the township from Upper Nazereth east of Bath, takes a westerly direction, crossing the railroad half a mile south of Bath, continues on to the south-west for a mile, turns to the south for ¾ of a mile, then turning to the west passing through Jacksonville and then along to the west, keeping south of the road leading west from Jacksonville.

Limestone outliers. There are three outlying patches of limestone in the north-western part of the township shown on the map. They are probably brought to the surface by the *anticlinal* which enters the slate south-west of Bath. Their shape cannot be accurately defined owing to the surface being covered with loose slate.

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98. Chester county quarry is 200×250×130 feet deep. The slates dip 20°, S. 40° W. *Cleavage horizontal.* At 10 to 40 feet from the top of the cut, *veins of quartz* show parallel to the bed plates. The slates are all thin bedded and the beds differ slightly in color. Some few of the slates have a small amount of iron pyrites in them. The blocks coming out of the quarry are large and even in size. Some of them are 20 feet long 4 feet wide and 2 feet thick, but do not seem to split well. There is a little water in the quarry. It is worked by two cable derricks, run by one forty-horse power engine.

At the corner of the road just north of the quarry there is an abandoned quarry, full of water.

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99. A limestone quarry, 1000 feet west of the Chester slate quarry. The dip of the limestone is 20° to the west. On top of the quarry there is a body of *slate* which is *non-conformable to the limestone*. The slate is somewhat broken and has probably fallen down on the eroded limestone.

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100. A. Koch's quarry, on Catasauqua creek 3 miles west of Bath, is 200×100 feet, and full of water. Dip 15° to the north. Cleavage 5° to the south. The slates are thin bedded. On the dumps the beds have bleached to a different color. Some iron pyrites show in some of the slates.

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101. One quarter of a mile south of Koch's quarry the limestone outcrops, dip flat, with loose slate on top of it. 1,000 feet south of this more limestone outcrops, and about 50 feet lower the slates show. There is a small cut in the bottom of the hollow at this place but it is full of water and nothing could be seen.

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102. At the saw-mill, dark blue, thin-bedded limestone outcrops with a dip of 30° to the S. 30° E. There is a small amount of *graphite* on the bed plates. Just south of this outcrop of limestone, gray slates show, dipping 30° to the north, and at the road leading west from Jacksonville gray cement stone show dipping 35° to the south.

Allen township.

104. South of Kreidersville the slates dip 20° south and the cleavage 20° south.

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105. On the railroad at the north-west corner of the township the slates have a slight dip to the south, averaging about 5° with rolls and twists and a few small vertical *faults*,

the cleavage is indistinct, dipping about 40° to the south. At the center and north end of the same cut the slates are flat with rolls and twists. Everything is contorted. The slates are thin bedded.

---

106. An abandoned quarry lies a few hundred yards east of the railroad near S. B. Hoffman's house, having about 5,000 cubic yards taken out of it. The slates dip 10° to the south 10° E. The cleavage is parallel to the bedding. A few *quartz veins* show in the slates which are thin bedded.

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107. An abandoned slate quarry 1¼ miles north of Siegfried's bridge on the Central Railroad of New Jersey is 75×50 feet, full of water, probably 25 feet deep. The dip is flat. Cleavage probably flat. Thin bedded slates. Those on the dump are bleached to a dirty gray.

Lehigh township.

108. S. Reple's quarry.—Across the road from the hotel at Rockville is an abandoned quarry 100×200 feet, full of water. For 500 feet north along the foot of the hill there are several small openings showing the slates flat and dipping 20°, S. 10° E. Cleavage dip 65°, S. 10° E. At the main opening the slates are flat. One bed shows in the bottom of the small cut 7 feet thick, all the other beds seen are smaller.

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109. Three quarters of a mile south of Rockville there is the outcrop of a large bed of slate which has the appearance of good roofing material. The cleavage is 60° south.

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110. East of Harper's grist-mill an outcrop of small slate beds show, dipping 20°, S. 50° W. The cleavage dips 60° south.

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111. Old Harper's, now *Henry's quarry*, half a mile south-east of Danielsville. The dip is steep to the north

155. OLD QUARRY NO. 2. (PAGE 116) AT SLATINGTON, LEHIGH COUNTY, PA.- LOOKING WEST. (PICTURE REVERSED.)

ARTOTYPE E. BIERSTADT, N. Y.

45° W. The cleavage is 45°, S. 10° E. The beds are small, with small tight ribbons. The *cleavage* in this quarry is *not parallel to the strike*, but the strike of the rocks is not parallel to the mountain; if it were continued it would strike the mountain at from a mile to two miles and a half. The slates look good, some of them are of a different color, separated by a wavy line but no ribbon.

200 feet south of the quarry is an old opening now being filled up.

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112. J. Henry's quarry, (Fig. 8,) one quarter of a mile south of Harper's quarry, is 200×150×30 feet deep. The quarry shows a regular *synclinal* axis with the cleavage at the center and north side of the quarry vertical, but on the south side it appears to be about 60° south.

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113. Eagle slate quarry.—F. M. Hower. ¼ of a mile south of Harper's there are two openings in a line with each other, the east one being slightly to the south-west. They are separated by 50 feet of rock. The dip is 80°, S. 10° E. Cleavage 60°, S. 10° E. There are no large beds, the cleavage being nearly parallel with the bedding. Blocks of from 20 to 30 feet in length are sometimes obtained. They make about 80 squares a day and also a few school slates. The quarries are about 100×200×60 feet.

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114. McChunk and National quarries.—These two quarries one third of a mile east of the Eagle quarry are close together. One of them is 100×150 feet and the other 250×250 feet, both full of water. In the northern one nothing can be seen as the water was up to the surface. In the southern one the rocks appear to dip 80° to the south with a cleavage dipping 40° to the south. The beds that can be seen are small, the largest one not over 5 feet thick, but only 50 feet of the 250 feet in the quarry is exposed. The slates left on the pile are thick and have a poor ring.

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115. Uplinger & Griffiths' quarry and Uplinger & Henry's quarry (Fig. 9.) These two quarries are 150 feet

apart; 500 feet south of the Eagle quarry is Uplinger & Harper's quarry. The slate dips 80° to the north. The quarry is not worked, as it is full of water. 150 feet south at the north end of Uplinger & Griffiths' quarry the slates are flat; for 300 feet more an occasional outcrop shows a flat dip; at the south end of the quarry, where they are now working, a *synclinal* axis shows. None of the beds are large. The slates look good and are of a darker color than most of the other quarries.

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116. Continental quarry, $1\frac{1}{4}$ miles south of Danielsville. The quarry is abandoned and full of water; it is 200 feet square; the slates dip 80° to the south, and the cleavage is 45° degrees to the south. One bed shows 10 feet thick in the middle of the cut.

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117. An abandoned quarry, $\frac{1}{4}$ of a mile east of Danielsville and 200 feet north of the strike of the Continental quarry, shows a flat *synclinal*, with the cleavage dipping 60° to the south.

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118. Col. B. Mourer's slate factory is one mile north of Poplar Grove, where they make about 2000 school slates a day.

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119. Newville Slate Co.'s quarry, one mile north of Poplar Grove on the south bank of Bertsch creek. The dip of the slate is 42°, S. 10° E. the cleavage 75°, S. 10° E. It is a side hill cut 75×125 feet and 90 feet deep at the face. The ribbons are tight and some of them jet black. The largest bed is 15 feet thick. The slate appears to break irregularly. The following are the thicknesses of the beds: The bottom bed 15 feet, then 4 feet of small beds; one bed 15 feet thick; 25 feet of small beds, and one bed 10 feet thick on top.

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120. New York and Pennsylvania quarry, $1\frac{1}{4}$ miles north of Poplar Grove. The quarry is abandoned and full of water. It was *reported* to me that the quarry was not

good, owing to the cleavage being imperfect and the slate rocky. Owing to the water nothing could be seen.

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121. Kester's Meadow quarry, leased by John Pauls and Peters, is 150×100×60 feet, and has from 10 to 15 feet of loose slate on top. The largest bed is 24 feet thick, other beds are smaller. The blocks come out of the quarry in large, even pieces; they split well and the slate looks good. They are now working on the large bed. The quarry is worked on the south side of the *synclinal* axis, and the cleavage dips about 45° to the south.

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122. Doddridge quarry, leased by Joseph Roberts, has just been started. The cut is down 30 feet, showing one bed 11 feet thick, with a few small beds on top. The dip is 70° to the south 10° E. Cleavage 55°, S. 10° E. This quarry is 500 yards north of the Kester Meadow quarry.

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123. J. Remley's quarry, one mile east of Walnut Port, is a small cut, not worked, 15 feet deep, full of water. The dip is 60°, S. 10° E. Clevage 50°, S. 10 E. There are two large beds reported in this quarry, the largest one 10 feet thick; they probably mean 10 feet along the cleavage. The slates on the dump looked good.

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124. Heinbach's quarry (Fig. 10), 1¼ miles north-east of Walnut Port, leased by Caskie & Emack.

The section of the eastern face of the quarry shown in Fig. 10, gives the structure. The quarry is 100×200×60 feet. The main cut was originally 150 feet deep. It is now partially filled by waste. It is now being worked by two tunnels, one driving to the east and the other to the west. The main opening shows the rock about vertical, but Mr. Caskie says that in the bottom they turned towards the north. The joints are mostly horizontal and quite persistent but are some distance apart, allowing large blocks to be taken out. In each of the tunnels there is a joint at the roof. The largest beds are from 10 to 15 feet thick, making along the cleavage about 25 feet. The whole 150 feet of the

breadth of the quarry is used for making roofing slate. There is a factory at the quarry for making school slate with a capacity of 10,000 cases a year.

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126. Owen Williams & Co.'s quarry, a quarter of a mile west of Heinbacks. is 200×100×80 feet. There is 60 feet of slate, used for roofing and school slates. The largest bed is 8 feet thick; there are other beds from 6′, 3′ and 4 feet thick.

100 feet west of this quarry Mr. David Williams has opened a quarry. He has only the *gravel* stripped off, which is about 20 feet deep. The beds he expects to strike are the same as in Owen Williams & Co.'s quarry.

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127. Williams & Jones' quarry, just west of Owen Williams' quarry, is 200×100×90 feet. The dip in the bottom of the quarry is vertical. At the south side near the surface there is a roll in the rocks shown. The cleavage is 60°, S. 15° E. In this quarry there is a bed of slate from which they make the slate pencils.

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128. An abandoned quarry, just north of Walnut Port, 200×200 feet, full of water. Nothing can be seen at it.

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129. On the railroad above the dam, the dip of the slates is 30°, S. 10° E. Cleavage 60°, S. 10° E. 100 feet further north the dip is 25° to the N. 20° W. Cleavage 60°, S. 10° E. Just above this an *anticlinal* shows with a flat cleavage. 100 feet further north the slates dip vertically.

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130. A few hundred yards south of the wagon bridge the slates dip 50° to the south.

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131. A short distance from where the wagon road goes under the railroad, massive gray *conglomerate* shows, dipping 30° N. 30° W. It is made up of white and black pebbles averaging one inch in diameter. There are also fine-grained gray *sandstones*. The junction of III and IV is not

159. (PAGE 117) AMERICAN SLATE QUARRY NO. 1. SLATINGTON, PA., LOOKING S. W. (PICTURE REVERSED.)

ARTOTYPE, E. BIERSTADT, N. Y.

visible, but the slates 50 feet below are seen gradually turning into sandstone.

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132. 100 feet north of the road crossing, is the last place the slates are seen and is 50 feet below the sandstone of IV. 250 feet south of this an *anticlinal* in the slates is seen in the side of the road. The axis of the anticlinal is about vertical, and the cleavage is parallel to it.

---

133. Two thirds of a mile south of Walnut Port the slates dip 75° south. There are some small beds of inter bedded *sandstone* at the same place.

---

134. Just east of Treichler's station the slates dip vertically. 100 feet each side of this the dip is flat.

---

135. Bech, Barge & Co's quarry, one mile below Treichler's, cuts into the side of the hill at the east side of the railroad. Is 50 feet deep at its face. The dip is 15°, S. 10° E. Cleavage the same. The slates are thin bedded, dark blue with a good ring.

---

136. On the railroad, at the township line there are three peculiar curves showing in the slates. The cleavage is parallel to the axis of these curves. In the first one the axis dips 5° to the south. 500 feet north and under the above there is another flat turn with the axis horizontal, then 300 feet further north there is a flat turn with the axis dipping 10° to the south.

B. Notes of quarries in Lehigh county.

Washington township.

138. 1¼ miles north of Slatington the slate dips 25° south. The cleavage 55° south.

---

139. 500 feet south of the saw-mill the slates are flat.

140. Abandoned quarry.—One mile north of Slatington is seen 25×100 feet, a side hill cut 25 feet deep. The dip of the slate is 25° to the north. Cleavage 60° to the south.

---

141. At the southern end of Slatington the slates in the river are vertical.

---

142. 200 yards south of C. Zellman's on the railroad, fine-grained sandstone outcrops. Dip 20° to the south. The largest layers are 4 feet thick. 40 feet of *sandstone* shows. 50 feet further south a *synclinal* shows with the sandstone on the south side of it vertical.

---

143. 300 yards north of Rockdale the slates dip 45° to the south. The cleavage parallel.

---

144. At the water station the slates are flat. Just south of the run the dip is 25° north. The rocks are slaty *sandstone* and slate. Then for over a quarter of a mile south the slates are flat. They then change gradually to a dip of 25° to the south. In the next 200 yards the dip changes gradually to 15°, N. 45° W., making a *synclinal* axis between these two points. 500 yards further down the railroad the dip is 20°, S. 45° west.

145.

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146. Captain D. D. Jones' new quarry.—Capt. Jones is engaged in opening up a new quarry on Welch run half a mile north of Slatington. The opening is fifty feet square and thirty feet deep. The slates dip 10° south and pitch 12° to the west with the cleavage vertical. They have sunk on to a big bed of slate a few feet. This bed outcrops several hundred feet to the east and is thirty feet thick. Twenty feet above the big bed there is a bed seven and a half feet thick. The other beds in the quarry are smaller. The slates made have a good ring, dark color and even cleavage. At the time of visiting the quarry they were

sinking on the big bed. The quarry is worked by horse power.

---

147. Welchtown quarry, John T. Robinson & Co., was opened 38 years ago. There are two large beds, one 27 feet along the cleavage, and another one on top 18 feet. They are separated by 25 feet of smaller beds. The quarry is now making 8 squares a day. It is being worked by a tunnel which goes on a 27 foot bed, which is the only one worked at present.

---

148. Williams' railroad quarry, a few hundred yards north of the Slatington depot, is about 100 feet square by 100 feet deep.

---

149. Old Keystone quarry is not being worked, it is 200 feet north of the Williams RR. quarry, and a side hill cut 200 feet square, 60 to 80 feet deep at the face. There are 2 large beds showing one 16 feet, then 10 feet of small beds, then a bed underneath of 25 feet. The slates dip 30° to the S. 10° E. cleavage vertical. The dip is the same all the way to the Williams quarry. 150 feet south of the Williams quarry the slates dips 70° south. Cleavage 30° south.

---

150. Tunnel quarry.—On Trout run 300 yards above the river, works one large bed back of the tunnel. There are two smaller cuts along side the tunnel that have fallen in.

151.

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152. An abandoned quarry.—Just above the Borough bridge on the south side of Trout run is a side hill cut 100 ×50×40 feet at the face. The slates dip 32° south. The cleavage dips 64° south. There is from five to twenty feet of loose slate at the surface, the beds showing are all small being under four feet in thickness.

---

153. Penlynn quarry is 150×150 by about 100 feet deep, dip 60°, S. 10° E., cleavage 40°, S. 10° E. There is a 20 foot

bed in the quarry. The other beds are smaller. The most of them are workable. North of the quarry 100 feet the slates dip 90°; 200 feet further north they are flat.

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154. Old Quarry No. 1.—500 feet north 40° east from the Penlynn quarry, on the north bank of Trout run east of Washington quarry. The slates are vertical, the cleavage dipping 60° south. There are two 10 feet beds of slate with smaller beds between them showing in the quarry.

---

155. Old Quarry No. 2, (Fig. 11,) is around the curve in the hill from quarry No. 1.

The quarry shows a *synclinal axis* with the plane of the axis dipping 70° to the south. The cleavage also dips 70° to the south parallel to the plane of the axis. It also shows the *bed thickening* as it curves around the axis from 27 feet thick to 35 feet. Just after the curve the distance from where it is 27 to where it is 35 feet is 50 feet.

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156. Old Quarry No. 3, is a short distance further down the creek from No. 2. The cut shows one large bed 20 feet thick dipping 28° to the south. The cleavage is 75° S. The quarry is not worked.

These three quarries belong to James Hess & Co.

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156 a. Washington Quarry, James Hess & Co., is 300×200×75 feet deep. The east end of the quarry has been partially filled with a slide of loose material. At the south side of the quarry the slates are flat at the middle of the quarry, they turn sharply downwards, the dip becoming vertical. The cleavage is 60° to the south. There are two large beds in the quarry, the upper one fifteen feet thick; then twelve feet of small beds; then a bed twelve feet thick.

---

156 b. Blue Vein Quarry, 200 feet south of the Washington quarry, has the same beds in it. The quarry is 200×150×75 feet. There is a *synclinal* axis showing in the quarry, the axis dipping 60° south. There is an *anticlinal* between this quarry and the Washington. Under the

159. (P. 117) AMERICAN SLATE QUARRY NO. 2. AT SLATINGTON, LEHIGH CO. (PICTURE REVERSED.)

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twelve-foot bed there is a school-slate bed. The lower four feet of the big bed has rock in it. The ribbons, when they get under thirty or forty feet of cover, become tight. At the south side of the quarry the slates are bent. This *synclinal* axis passes north of the Penlynn quarry through Slatington, and shows in the Tunnel quarry. It does not show at the river, probably owing to a want of exposure.

---

157. Blue Mountain Quarry, (Fig. 12,) 600 feet in length from east to west and 250 feet at its widest part, is 120 feet deep. The slates at the surface are loose from 10 to 15 feet down. The quarry shows the following section: The two large beds are 16 and 27 feet thick, separated by 12 feet of smaller beds. The quarry was started from 35 to 40 years ago, and was originally worked by Williams & Moser. It is now worked by 4 spar derricks and 1 large cable derrick. They are making about 55 squares a day.

---

158. Columbia Quarry, on the north side of Trout run north of the Blue Mountain quarry, is 300 feet long; dip vertical; cleavage 20°, S. 20° E. There is from 10 to 30 feet of loose rock on top of the quarry.

500 feet south of the Columbia is an old abandoned quarry; the dip of the slate is 70°, N. 20° W. The cleavage 50°, S. 20° E.

150 feet south-east of this the dip is 10° north.

---

159. American Quarry, No. 1 and No. 2, (Fig. 13,) west of Columbia. Quarry No. 1 is 250×100 feet. There are two large beds 30′ and 20 feet thick, separated by 6 feet of small beds, one of these small beds being 2 feet thick. Just west of No. 1 is the American No. 2 quarry, which shows the section Fig. 13.

---

160. Girard quarry, half a mile west of Columbia on the north side of Trout run. The quarry is 250×100×50 feet. It is not worked and full of water. There is one bed 15 feet thick showing.

161. Star Slate quarry is 300×100×60 feet. The slate dips 70°, S. 10° E. and the cleavage 50°, S. 10° E. There are two large beds 27′ and 18 feet thick. The quarry has 10 feet of clay on top of it, and 4 feet of blue slate underneath the clay.

---

162. Williams, Owen & Jones' quarry.—A small quarry 40 feet deep and 100 feet square, in a line with the Star quarry, which shows the slate turning over towards the south. They have one derrick, worked by horse power, in operation and are working on the 27-foot bed.

---

163. Franklin quarry (Fig. 14) is 1½ miles west of the Slatington depot and north of Trout run. (There are several old openings south of it towards the Star quarry.) The Franklin quarry proper is on a flat *synclinal* and is worked by 4 spar derricks and one cable derrick. The quarry is 150 feet deep at the deepest place.

---

165. Junction quarry is opposite the junction of the Slatedale branch railroad. It is abandoned and full of water. Is 200=100 feet square and shows one bed 15 feet thick. The rest of the beds are all small. The dip is steep to the south, and the cleavage is about 50° to the south.

200 feet north of this is a small quarry 50×50 feet, full of water, and nothing could be seen.

On the Lehigh and Berks railroad south-east of the junction quarry a flat *synclinal* axis shows with a vertical cleavage.

---

166. Industrial slate quarry is 300 feet north of the Junction quarry. They are working on the 20 foot bed. The quarry is worked by horse power. They are making about 15 squares of slate per day. The slate dips vertically on the surface, curving towards the south at the bottom of the quarry. The cleavage is about 45° to the S. 10° E.

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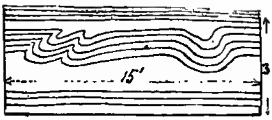
167. An abandoned quarry 1000 feet west of the Industrial quarry, full of water, 200×200 feet. Probably 40 feet deep.

Fig. 7 No. 97



8. Outcrop, No. 109.

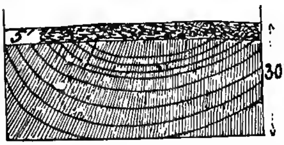


Fig. 10. Heinbach's Quarry. No. 124.

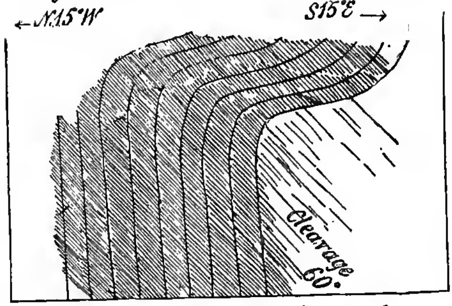


Fig. 9 Uplinger & Griffith's Q. No. 115. Uplinger & Henry's Q.

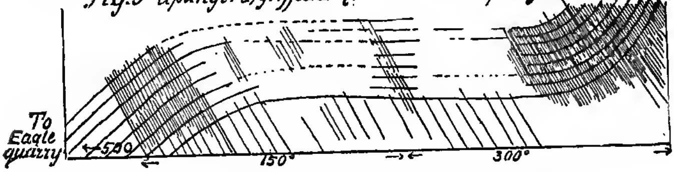


Fig. 11. Old Quarry No. 2. No. 155.

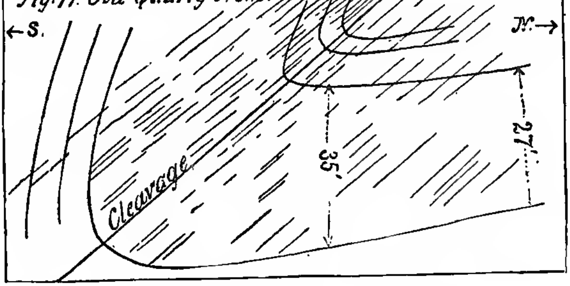
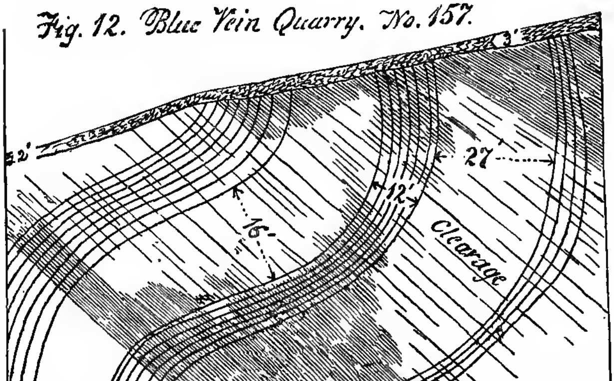


Fig. 12. Blue Vein Quarry. No. 157.



There are three other openings besides this. The largest one 300×100 feet. All of them full of water. There is one large bed 15 feet thick.

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168. An abandoned quarry 1500 feet from the east end of Slatington. Its section is shown in the section of the Blue mountain quarry.

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169. Blue Mountain slate quarry, (Fig. 15,) 250 feet north of the above quarry, is 200×40 feet wide by 60 feet deep. The largest bed is 27 feet thick. The slates dip 60° north. The cleavage is about 60° to the south. At the bottom of the large bed the cleavage is slightly curved. The section of the two quarries is shown in Fig. 15.

---

170. Monarch quarry, owned by Mr. Hersh, on the south side the creek from the Blue Mountain quarry, shows the same beds with a dip of 15° to the north and is not being worked.

Across the road there is another abandoned quarry in which the slates dip 70° to the north, and the beds appear to be the same as those in the last quarry.

There are two other quarries in the same field as this one. The largest is 150×150 feet and probably 50 feet deep.

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171. Lock Slate quarry, (Fig. 16,) one quarter of a mile west of Slatedale. At the south-east end of the quarry there is a small opening 50×50×50 feet showing a bed 15 feet thick, dipping 85°, N. 10° W., with a cleavage dipping 70°, S. 10° E. The main quarry is 400 feet in length. They are now working a quarry under ground by means of two slopes going down on the large bed. The hoisting is done by means of cable derricks worked by one engine. The inclines are three feet apart. The structure of the quarry is shown in the section Fig. 16.

---

172. Standard quarry, one quarter of a mile north-east of Slatedale, is 300×50×114 feet deep. There are 3 large beds 20′, 8′ and 16 feet, with 3 feet of gravel and 6 feet of

Fig. 14. Franklin Quarry. No. 163.

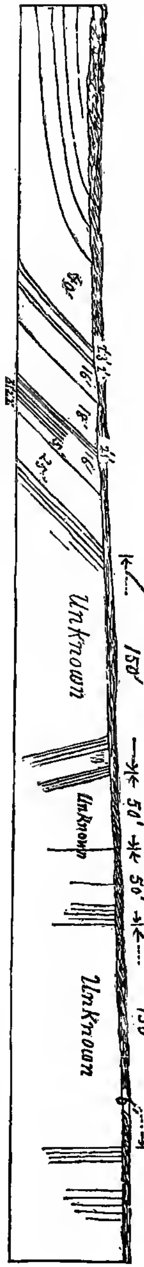


Fig. 13. American Quarry No. 1. No. 159.

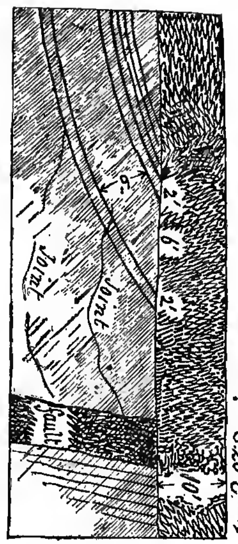


Fig. 15. Blue Mountain Slate-quarry. No. 169.

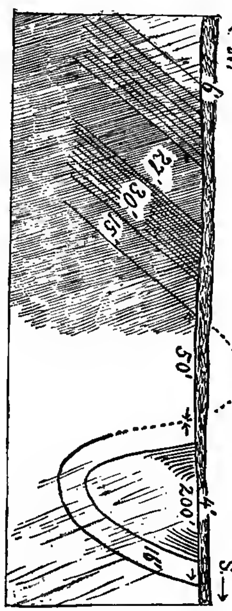
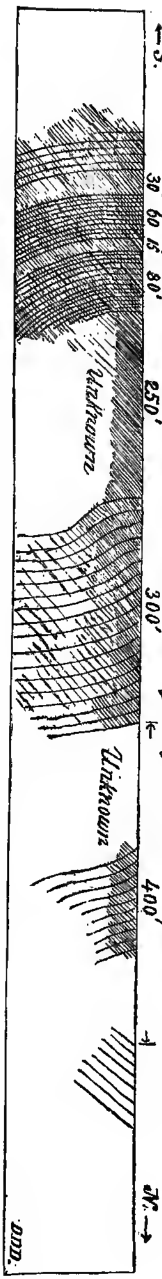


Fig. 16. Lock Slate-quarry. No. 177.



loose slate on top of the quarry. The 16-foot bed is the one worked. A large bed was opened at the west end of the quarry, but did not work well at that point. The rocks sculp and split nicely and come out of the quarry in good sized blocks.

---

173. Grey slate shows in the south-west corner of the township, dipping 30° S. 20° W.

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174. Gray slates, dipping 90° south. The *sandstone* that shows on the railroad one mile below Slatington makes a high hill that extends west over 2 miles from the river. No solid sandstone shows, but the ground is covered with loose pieces.

North Whitehall township.

175. North Peach Bottom Slate Co.'s quarry, 2 miles south-west of Laury's Post Office, is 250×200×90 feet deep at the deepest place. The slate beds are horizontal, with slight rolls in them. The cleavage is about horizontal. The joints are vertical, but make different angles with each other. They are capable of taking out blocks 20 feet square. The largest bed between loose ribbons was 3 feet thick. About 30 feet from the surface, there are seggregated *veins of quartz* that split the cleavage for some distance around the veins. On the top of the quarry there is a bed of sandy slate which does not split well, while the slates made of which there are only a few squares to be seen, are black with a good ring and smooth surface, but the second quality slates have a very uneven surface and look poor. There is a factory connected with the quarry that was engaged on an order for flooring for the Patent office in Washington.

---

176. There are very few exposures in the township at which the dip can be obtained. On the small creek that empties into Jordan creek in the south-west part of the township, there are two dips to be had just east of the school-house, the slate dips 10° to the south and a quarter

of a mile above the mouth of the creek the slates are flat, with a few small rolls in them for a half mile on each side.

Heidelberg township.

177. At the south end of Germansville, the slates dip 55° south.

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178. On the Jordan creek one mile east Pleasant Corner, a sharply folded *anticlinal* shows, dipping 60° to the south. On the south side the dip is 50° south; on the north side it is 70° south.

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179. Half a mile south the slates dip 50° south.

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180. 1½ miles up a small creek that runs into the Jordan at this point, there is an abandoned slate quarry with nothing to be seen.

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181. One quarter of a mile east of Pleasant Corner the slates dip 30° S. 20° E.

---

182. *Diamond Slate quarry*, (Fig. 17,) leased by Bartly & Bar, was opened 28 years ago. It is 250×150 feet. There are two large beds, one 24 and the other 30 feet thick, separated by 5 feet of small beds.

On top of the 24-foot bed there a few *quartz veins*, there are a few also in the slates above the 24-foot bed, the beds rise slightly to the east along the strike of the rocks.

500 feet north of the main quarry is an old abandoned quarry, the slates dipping 45° S. 10° E. It has all fallen in and nothing is to be seen.

South Whitehall township.

183. An abandoned slate quarry on the Huckleberry ridge synclinal ½ a mile south of Guthsville is 200×100 feet, full of

water. The slates are vertical. The cleavage dips 45° to the south, and the slates are all thin bedded.

Low Hill township.

184. As the north-east corner of the township the slates dip 15° S. 60° W. ½ mile further down a small run the dip is 45° north with a cleavage dipping 45° south, the cleavage has a curl in it. Just below Low Hill on the Jordan the slates dip 50° south, the cleavage is curly. A few hundred yards further down the slates dip 30° south.

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186. 1½ miles down the creek the slates dip 50°, N. 10° W. They are dark blue and thin-bedded with no regular cleavage. ½ mile further down the dip is 50°, S. 20° E. Slates massive and cleavage irregular.

---

187. In the road across the Weidasville bend in the creek the ground is covered with pieces of quartz. 1½ miles down the creek from Weidasville the slates are flat.

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188. Half a mile south of Low Hollow Post-Office the slates dip 50°, S. 10° W. The cleavage parallel to the dip.

---

189. At the north-west corner of the township the slates dip 80° south.

One mile north-east of Lyons Valley Post-Office the slates are flat.

---

190. One mile south of Claussville the slates are flat, and on the creek in the southwest corner of the township there are segregated veins of *quartz* showing in the slate.

Lynn township.

191. 1½ miles east of Lynnport. the slates dip 55° to the south.

192. Laurel Hill Slate Co's. quarry.—Is one mile north east of Lynnport. Is 75×50×60 feet deep. The dip is vertical. Cleavage steep to S. 40° E. The beds worked are 26′, 10′, 8′, 6′ and 2′ in length along the cleavage.

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193. Lynnport Slate quarry, at Lynnport north of the railroad is 150×100×60 feet.

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194. At New Slateville there are two abandoned quarries. The one beside the road shows the northern half of the *anticlinal* axis, with one bed 4 feet thick. The others that are above water are small. The other quarry shows the slate dipping about 45° to the south with one bed 4 feet thick showing.

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195. Star Slate quarry, (Fig. 18) George W. Greesiemer & Bro., at New Slateville, one mile north-west of Steinville, was started 13 or 14 years ago. Worked by the present owners since 1876. They make about 7,500 sqares a year. The cross section Fig. 18 shows one large bed 30 feet thick.

C. Notes of quarries &c. in Berks County.

Albany township.

195. Centennial quarry, 1½ miles west of Steinsville, owned by Faust Heinly & Bros., is 150×50×80 feet, the slates dipping 80°, N. 20° E. The following section shows the quarry and a small opening made on the large bed to the south.

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196. An abandoned quarry, east of the Centennial quarry nearly on the county line, shows a bed 20 feet thick dipping 70° to the north, with the cleavage vertical.

Weisenburg township.

197. 1½ miles north-east of Seiberlingsville an out crop of *red slate* shows in the road, but it is not roofing slate.

198. One mile north of Seiberlingsville, along the curve of the hill, there is an outcrop of thin bedded gray *sandstone;* also, some light green slate. This outcrop shows for about a mile.

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199. An old quarry, east of Siepstown, near the township line, is 10 feet deep. Dip 70°, S. 20° E. Cleavage 20°, S. 20° E., which is tolerably perfect. The slates look like good roofing slates.

---

200. One mile south of this the slates dip 10° to the north. ½ a mile further south, in upper Macungie township, the slates dip 20° to the south.

Albany township.

At Trexler's Station the slates dip 20°, S. 20° W. ½ a mile west they dip 45° to the south. Just east of Mountain Post-Office the dip is 64°, S. 10° E. ½ a mile west of the Post-Office it is 80°, S. 20° E. 1½ miles west of the Post-Office the dip is 63°, S. 10° E. Going on west into the cove at *Digby Miller's* the dip is 80°, S. 10° W. At S. Knesler's it is 52°, S. 10° E. At William Bolick's it is 90°, S. 10° E., and, also, near the same place it is 75°, S. 10° E. At John Berg's it is 90°. At this place there are thin bedded dark gray slates, with inter-bedded *sandstones.* The sandstone is fine grained and in thin layers. The outcrop shows 500 feet of slates and sandstones. At the new Bethel Church the slates are vertical. Just north of the church they dip 45° to the south.

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205. John Gilt's flagstone quarry is two miles from Kempdon Station. The *sandstone* dips 65° south. The strike of the rocks would carry it directly into the point of the mountain. The sandstone comes out of the quarry with rough faces, but after being dressed it looks good. Just north of this quarry the slates dip 35° south.

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206. One mile east of the above quarry there is *red slate*

Fig. 17. Diamond Slate quarry. No. 182.

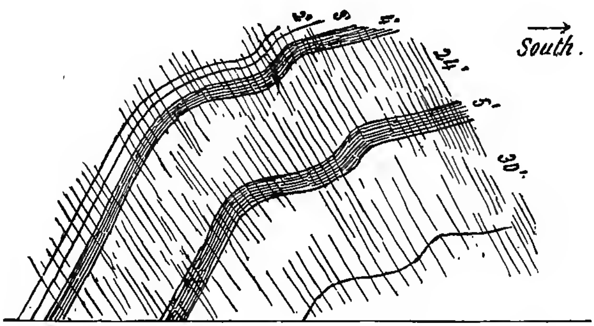
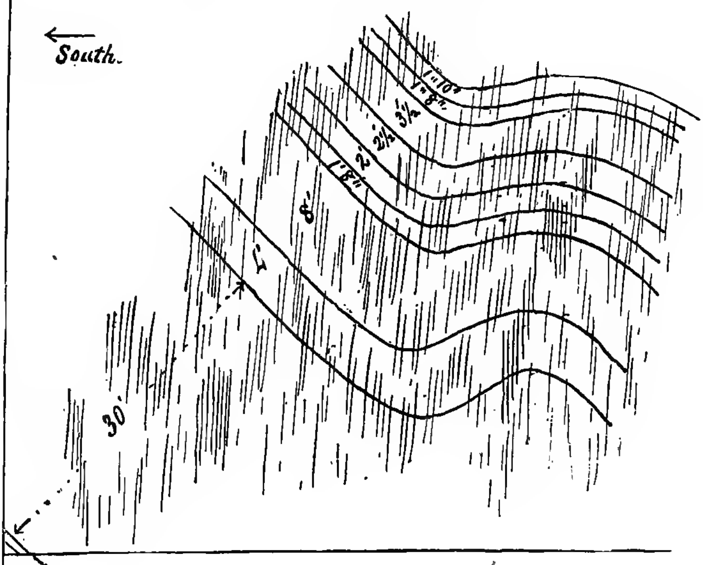


Fig. 18. Star Slate quarry. No. 195.



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with a dip of 20°, S. 10° E. The slate has patches of green in it.

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207. On the road just below the Grist-mill the slates and interbedded *sandstones* dip 45°, S. 20° W. 200 yards south red slates about 40 feet thick show. Dip about 60° south.

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208. Opposite the school-house, light greenish *sandstone* outcrops. It makes the high ridge to the east called Round Top. 1000 feet further down *red slate* shows.

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209. ¾ of a mile south of the Grist-mill thin bedded olive slates show, dipping 80° north.

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210. A shaft on Stone run, 1½ miles above its mouth. There is down on *red slate.* The shaft is about 20 feet deep. The red slate is 20 feet thick. Some of it has spots of green in it; also, some green slate. They did not get any roofing slates. The slate has not a good cleavage.

---

211. One half mile north of this, a gray *sandstone* outcrop dips 90°, S. 10° W.

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212. Half a mile north of Wessnersville slates dip 45°, S. 10° W. Half a mile south of Wessnersville *red slate* outcrops dip 90° south.

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213. Two miles south-east of Wessnersville olive slates dip 50°, S. 30° E.

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214. One mile west of this outcrop *red slates* outcrop.

Greenwich township.

215. On the railroad, ½ a mile west of the township line, the slates dip 58°, S. 20° E.

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216. Opposite Lenhartsville, slates and thin bedded sand-

stone dip 55°, S. 20° E. At the road crossing, *red slates* show.

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217. On the small creek 2 miles N. E. of Lenhartsville *red slates* outcrop. Dip 55° south.

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218. One and a half miles east of Smithsville, a fifty foot outcrop of *red slate* shows in the road.

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219. Half a mile north of Smithsville, *red slates* outcrop.

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220. Two miles west of Smithsville, 15 feet of *red slate* shows. Dip 55°, S. 30° E.

At Klinesville, *red slate* outcrops.

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221. The hill a mile south of Klinesville is made of fine grained, thin-bedded *sandstone*. On the south side of the hill *red slates* show in layers as far as the school-house, and along the road to the east for a mile and a half.

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222. One mile south of Smithville slates dip 20°, S. 40° W. Half a mile further there is an outcrop of massive flaggy *sandstones*. There are two small outcrops of *limestone* in the township; the northern outcrop is on S. D. Kohler's farm. The length of the outcrop cannot be traced, owing to loose slate covering it. Just north of this outcrop the slates dip 35°, S. 20° E.

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223. The other outcrop is half a mile south of W. Heffner's grist-mill. The dip is 10° north. The *limestone* is blue and thin bedded.

Maxatawny township.

224. One and a half miles north of Kutztown the slates are flat. ½ a mile north of this and on top of the hill above the junction of the slate and limestone, the slates are flat, but at the lower side of the same cut the dip is 45° west.

One mile east of Monterey olive slates show, with a dip of 50°, S. 30° E.

Richmond township.

225. East of Virginsville one mile, the limestone outcrops. The most northern outcrop dips 30° north. A quarter of a mile south, with slate showing between, the limestone is flat with rolls in it. Half a mile south of this, with slate between, the limestone dips 30° north ; it is dark blue, thin bedded, and shows 100 to 200 feet, and has the appearance of the *Trenton.* Along the small creek half a mile east of this there is no limestone to be seen.

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226. 2½ miles east of Virginsville there is an outcrop of thin-bedded *sandstone* dipping 30° south.

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227. Three quarters of a mile east of Merkel's saw-mill slates dip 90° W. There is some fine-grained *sandstone* also outcrops at this point.

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228. Just below Merkel's saw-mill slates dip 35°, S. 30° E.

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229. On the hill north of Moselem furnace slates dip 15°, S. 60° W.

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230. Three quarters of a mile south of Moselem furnace slates dip 20° north.

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231. One mile west of the furnace the dip is flat.

Windsor township.

232. At school-house No. 4 slates dip 90°, south 30° east, with some slaty sandstone.

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233. 300 feet south *red slate* outcrops and shows for half a mile east.

234. Half a mile south of St. Paul's church *red slates* show 600 feet across the outcrop. How thick I do not know as there was no dip. A quarter of a mile east the same outcrop shows with a dip of 60°, S. 30° E. One and a half miles east of Hamburg the slates dip 50° south.

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235. One mile east where the old railroad grading is, there are alternating beds of slate and *sandstone* dipping 52° S. 20° E. At the east end of Hamburg sandstone outcrops in the road.

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236. One mile north of Hamburg alternating beds of slate and sandstone show, with a dip of 75 S. 10 E. The dip is not regular but increases and decreases.

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237. One quarter of a mile below the lock-house the sandstone dips 10° east. Massive *sandstone of IV.*

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238. 500 feet further up the river dark gray slates dip 50°, S. 20° E. 200 feet shows underneath gray slate, slaty sandstone and thick bedded *sandstones.*

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239. One mile east of Hamburg, slates dip 60° S. ¼ of a mile further east fine grained olive sandstone, 15 feet thick, thin bedded, dips 80°, S. 10° E.

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240. South of the run *red slates* show. Outcrop 30 to 50 feet. Dip 50°, S. 10° E.

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241. One mile north of Windsor Castle slates dip 60° south.

242. Half a mile north of Windsor Castle slates dip 35° south.

243. One and a half miles east of Windsor Castle slates dip 60° south.

Perry township.

244. *A flagstone quarry,* at the north-east corner of the

township, worked by Jacob Derby. The stones make good flagging, and are taken out generally 2′×3′×3″ in size. Some are 10 feet long. They are dark gray and come out regularly. The sandstones roll to the north and south and dip to the north-east 20°.

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245. Half a mile west slates dip 50° south. 500 feet south *limestone* outcrops. Crop shows for 30 feet. This outcrop shows west for three miles. Just west of the Zion church it is flat with rolls in it.

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246. One quarter of a mile north of the church the slates dip 50° south. 1000 feet south of the limestone *red slate* outcrops. One mile south of the above *limestone* outcrop there is another which is about parallel to it.

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247. *On Peter Folk's farm* the *limestone* dips under the slate at an angle of 20° to the south. At the corner of the roads the slate dips 18°, S. 70° west.

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248. One mile further west the *limestone* dips 32° south. Light blue and broken.

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249. A mile and a half further west the *limestone* dips 20°, S. 20° E. Is light blue with some slaty limestone on top. The outcrop of limestone shows again at the creek above the grist-mill.

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250. *W. Collier's flagstone quarry*, three quarters of a mile north-east of Shoemakersville, is 150 feet long. 10 feet of flagstone exposed has from 5 to 10 feet of broken slate on top. Stones, from 2′ to 4′×5′ to 8′, show dark gray generally, 2 inches thick, with smooth faces. The joints are not regular, making a loss of about one third in squaring them up. Half a mile south-east of this quarry the slates dip 80° south.

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251. A small quarry, two miles east of Shoemakersville, is 20×30×10 feet, for *flagstones*. The stones on the pile are

6×6×3 feet. Quarry is full of water. One mile south the slates dip 50°, S. 10° W.

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252. At the north end of Mohrsville the slates are flat.

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253. 1½ miles north of Shoemakersville on the canal the slates dip 45°, S. 30° W. 200 feet further north the dip is 90°, N. 30° E. Might probably be the *anticlinal* that brings up the limestone further east.

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254. One mile further up the canal, the slates dip 60° S. 30° W.

Maiden Creek township.

Could not get any dips. The only thing to describe is the direction of the junction of II and III.

Ontelaunee township.

255. One mile north of Evansville, *limestone* outcrops show 100 feet wide.

---

256. 1¾ miles east of Leesport slates dip 55°, S. 20° E.

---

257. One mile north of Leesport, slates and some slaty sandstone shows. Dip 40°, S. 20° E.

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258. Crane Iron Co's. ore bank.—Two miles and a half N. E. of Leesport consists of two open cuts now full of water. At one place could get a slate dip of 45° south. The surface is covered with loose slate, and pieces of slate coated with hematite. From the looks of the dump I should say that the mine had a great deal of slate in it.

These same slates extend along the north side of the valley through Berks, Lebanon, Dauphin, Cumberland and Franklin counties into Maryland and Virginia. There are

no slate quarries opened west of the Schuylkill nor as far as I know have any explorations been made for roofing slates.

But as the same slates go on across the state and as the cleavage shown by the outcrops have about the same appearance there is every reason to suppose that there are many places in the above counties where successful quarries can be opened.

It must be borne in mind however that the whole slate formation will not make roofing slates; so that one or two small trial holes must not be taken as condemning the whole district. But a systematic search should be made, by trenching across the strike of the rocks where the surface indications are good.

The *red slate* which outcrops through the western part of Berks county on towards the center of Cumberland county needs careful examination, as some of the outcrops may be roofing material; they are not all of them good. As transportation is a large item in the cost of slates the localities near the railroads should receive attention first; that is, along the line of the Schuylkill, Swatara and Susquehanna railroad, and along the line of the Southern Pennsylvania railroad.

D. Structure of the slate belt.

(Figs. 19, 20.)

The exact structure of the slate belt cannot be worked out owing to a lack of exposures.

The structure is in general a series of anticlinals and synclinals which are closely folded and mostly overturned, the plane of the axes dipping to the south.

The lines of the axes are approximately parallel.

These axes may be divided for a general description into two series. The northern series or those nearest the mountain are those starting out of the long narrow limestone valley that crosses the Delaware from New Jersey at Portland.

At the Delaware the number and size of the axes cannot be made out. At the Schuylkill there are probably four.

The other system is made up of axes which enter the slate belt from the southern bordering limestone, as shown by the tongues of limestone which enter the slate at different points. The direction and extent of these anticlinals cannot be followed through the slates. These axes are all approximately parallel to each other and with the trend of the valley. From the few exposures that can be seen it can be said that the flexures are the sharpest and most overturned along the southern part of the slate belt, although those along the northern part are closely folded and often overturned.

The following cross-section through Slatington is the only continuous one that could be made.

The section shows over a thousand feet of slates. The Blue mountain quarry works the lowest beds, being only a few hundred feet above the top of the ribbon slates.

The following are the measurements of the different beds starting with the top:

	Ft.	*Ft.*
Unknown, but includes large known workable beds,	400	400
Small beds,	10	68
Bed,	7	
Small beds,	20	
Bed,	31	
Unknown,	100	100
Bed,	20	60
Small beds,	25	
Bed,	15	
Small beds,	100	100
Bed,	8	114
Small beds,	4	
Bed,	10	
Small beds,	40	
Bed,	12	
Small beds,	40	
Bed,	10	35½
Small beds,	12	
Bed,	13½	
Small beds,	50	100
Small workable bed,	—	
Small beds,	50	
Bed,	12½	111½
Small beds,	60	
Bed,	15	
Small beds,	12	
Bed,	12	

Unknown,	60	210
Workable bed in,	50	
Unknown,	100	
Small beds,	25	80
Bed,	16	
Small beds,	12	
Bed,	27	
Small beds and unknown,	—	150±
Total,	1529	1529

The upper four hundred feet contain the beds worked around Heinback quarry and those around Slatedale. Their position in the four hundred feet is unknown. Below this section comes the 3700 feet of ribbon slate.

The following can be taken as an approximate estimate of the position of the quarries, starting with the highest and going down:

1. Those at Pen Argyl; 2. those around the Heinbach quarry; 3. at Slatedale; 4. those north of Steinsville; 5. quarries around Slatington; 6. quarries around Bangor. Then come the ribbon slate quarries. Their position in the ribbon slates cannot be even approximated, excepting that the North Peach Bottom quarry and Chester quarry are within a few hundred feet of the bottom. The Cahman quarries and those around Belfast are probably near the center of the ribbon slate.

E. Roofing Slate Cleavage.

The cleavage of the slates through this district has dips of all strengths from the horizontal to the vertical, and are independent of the strength of the dip of the slates crossing them at all angles.

The strike of the cleavage dip and the strike of the rocks are parallel; with the following exceptions:

Half a mile north of Howersville, Lehigh township, the slates dip 20°, S. 50° W., while the cleavage dips 60° south. Here the strikes are at an angle of 50° to each other, but as the dip strike is in an abnormal direction, it may be owing to the rocks folding around a dying axis, while the cleavage dip keeps parallel to the actual strike.

At Henry's Quarry, ½ mile S. E. of Danielsville, the slates have a strike of N. 45 E. and S. 45 W., while the strike of the cleavage planes is N. 80° E. and S. 80 W. As this strike of the slate would carry the rocks into mountain from a mile to two miles to the N. E., it is probable that the slates are here bending around a dying axis.

At the following eighteen quarries and cuts the slates can be seen curving around their axes. In seventeen of them it will be seen that the planes of the cleavage dip is parallel to the plane of the axis.

While in one of them, Jory's Q., the two planes are at right angles to each other.

Whether in this case the cleavage is parallel to a stronger axis of elevation than the one showing in the quarry, or not, there are no exposures to determine.

The following list of observed directions of cleavage will be useful:—

195. Centennial quarry.—Cleavage shows parallel to plan of anticlinal axis. The axis is double. Have a small depression in its center. Axis vertical.

195. Star Slate quarry.—Cleavage shows parallel to synclinal axis, which pitches deeply to the south.

168. Blue Mt. Slate quarry.—250 feet south a synclinal shows the cleavage making an angle of about 10° with its plane. But there is an anticlinal 100 feet north, the dip of which could not be seen.

165. On Lehigh and Berks RR. above the junction of the Branch to Slatedale a flat synclinal shows, with vertical axis, and cleavage vertical.

164. See relation of cleavage to axis at the Franklin quarry.

157. In the quarry there are two curves in the slates, the cleavage being parallel to their axis. Dip about 30° south.

117. Old abandoned quarry in Lehigh township; synclinal shows, with cleavage parallel to its plane, both being steep to north.

112. J. Henry's quarry.—Synclinal shows plane vertical, with cleavage vertical.

39. Jory's quarry.—South of Pen Argyl synclinal shows

with the axis vertical; but the cleavage is horizontal. They are consequently at right angles to each other.

At the *Jackson* quarry which is a short distance south the cleavage is dipping 20° or 30° to the south.

At the *Pennsylvania* quarry which is several hundred yards north, the cleavage also dips 25° south.

41. Robeman's; cleavage flat.

42. West Washington quarry; cleavage flat.

37. Hull's; cleavage 15°, S. 10° E.

155. Old Quarry No. 2, Slatington, shows axis of synclinal dipping 70° to the south, with cleavage dipping also 70° south.

The big bed thickens from 27 feet to 35 feet at the bend of the axis.

136. On C. RR. of N. J. there are three flat curves in the slates, one of them is flat, another dips 5° to south, another 10° to south. The cleavage in each case being parallel to the plane of the axis.

132. In the Lehigh gap on east side of the river a small anticlinal shows with vertical axis. Cleavage also vertical.

124. Heinbach quarry; axis of synclinal dips 60° south. Cleavage also dips 60° south.

F. Quarrying slate.

The slates are all mined from open quarries. The quarries are worked by day labor, by contract, and by a mixed method of day labor and contract.

In working the quarry by contract, the owner lets the quarry out, agreeing to pay a stipulated price per square for slates delivered on the bank. The other contract method, which is the most common, is to let out parts of the quarry to gangs of men, who quarry and dress the slate, the owner doing the hoisting and delivering the blocks at the splitters' shanties.

From four to six men generally take a contract together.

The machinery necessary to work a quarry is a derrick, pump, one or more mine cars, a short track, several waste-

boxes, some chains, drills, hammers, crowbars, sledges, and splitting chisels.

The derricks used are the ordinary spar derricks, with a wooden mast and wooden boom with wire guy-ropes and worked with wire ropes. The hoisting is done by horse power, but mostly by steam. The other kind of derrick used is called a cable derrick; it is preferred by most of the quarrymen. A heavy iron or steel rope passes over a frame down into the quarry at an angle. The frame is made of three pieces of timber, twenty feet long by 10″× 10″, and a piece 16 feet 10″×16″. The three pieces 20 feet long are framed together in the shape of a triangle, with the 16 feet piece framed into the apex of the triangle. In the sixteen feet piece two slots are cut, in which are placed wheels to carry the cables. The upper wheel is placed so that its top just clears the top of the frame. The other wheel is put two or three feet lower down. The frame is then set up at a convenient place on the dump, some ten or fifteen feet from the edge of the quarry, so as to allow room for a track between it and the quarry. A wire cable from an inch and half to two inches in diameter is then passed over the upper pully, taken over to the opposite side of the quarry and fastened to an iron rod set in a drill hole on the side. The cable should be fastened low enough to make an angle of at least 10°. The other end of the cable is passed around a log, held in place by posts sunk into the ground. The cable is then stretched tightly over the pulley and fastened. Over this fixed cable a traveler passes. The traveler is made of an iron frame carrying four pully wheels; the two upper wheels work on the fixed cable. The hoisting rope passes from the winding drum, through a block at the foot of the frame, up through the sheave at the top, then through the first pulley on the traveler, down around a loose pulley, back around the second pulley and is fastened on to to the loose pulley. This loose pulley has a hook on its lower side to which can be fastened the waste-box or chains for hoistiug blocks of slate.

The hoisting is done by an engine of from thirty to forty horse-power. Those with double cylinders, working the

drum by friction clutches, seem to be preferred. The descent of the cable into the quarry is controlled by an iron strap brake around the drum, the engine being disconnected. The following terms being peculiar to the slate district, an explanation of them is given:

Cable-derrick. A derrick composed of a fixed wire rope descending into the quarry at an angle from a post near the edge of the quarry. Over this fixed rope a traveler passes composed of an iron frame with three to four wheels, the hoisting rope passing through the lower wheels, while the upper wheels travel over the fixed rope.

Curl. A slate rock in which the cleavage is curved and twisted irregularly is said to have a curl in it.

Ribbon. A thin bed of slate.

Ribbon slate. Slates that are made up of a number of small beds.

Sculp. To break a block of slate at an angle to the cleavage, (approximately at right angles.)

Split. Same as cleavage.

Square of slate. The number of slate necessary to cover 100 square feet on a roof

In starting a quarry after the position of the bed has been determined, the first operation is stripping the surface deposit and the weathered outcrop of the slate. The depth of this loose material varies from 10 feet to as high as fifty feet; it will average about twenty. It is usually done with pick and shovel and the material removed with horses and carts.

After the stripping has been done over a sufficient area then the work can be commenced of quarrying the slate blocks, this is done by means of drilling holes and blasting the slate. The position and direction of the holes require skill and good judgment on the part of the quarryman; it being not only necessary to move the largest amount of rock with the fewest holes, but which is of more importance the rock must be moved without shattering it, so that the greatest amount possible can be used.

The holes are generally drilled at right angles to the cleav-

age, and so placed that the full advantage may be taken of the loose joints and natural cleavage joints.

After the slate block is loosened from its bed, if it is not too large, it is hoisted to the surface by the derrick, put on a truck, and run to a slate-maker's shanty, and dumped on to the ground. One of the splitter's assistants then with a chisel and hammer cuts it into blocks of suitable size for splitting into slates. These blocks are about two inches thick and of sufficient surface to be capable of being dressed into finished slate of the various sizes. Supposing the block to come out of the quarry one foot thick, eight feet long and four feet broad—the bank-man takes a chisel and hammer and cuts a notch some three to six inches deep into the middle of the end of the block; then with a large wooden mallet he drives a chisel into the end of this notch, watching carefully the direction the crack takes. If it goes parallel with one of the sides he continues; if not, by using the mallet on one or the other sides of the notch he brings it back towards the proper direction. After he breaks the rock lengthwise into two, he then cross cuts it in the same manner into four pieces. Then with a flat chisel he splits each one of the foot-thick blocks through the middle, splits them again, until he has them reduced to a thickness of about two inches, and then these blocks are piled up beside the splitter.

The splitter takes a block and with a wooden mallet and a broad, thin chisel (he generally has two or more chisels of different lengths) he splits the block through the middle, and continues dividing the blocks into equal halves until they are reduced to the thinness of a roofing slate.

These thin pieces of slate with irregular edges are then taken by an assistant, generally a boy, and squared off into the regular sizes by means of a dressing machine.

There are two kinds of dressing machines in general use. They are made of an iron frame work some two and a half feet high, having a horizontal knife edge on its upper side. Working against this knife edge is a curved knife, working in a hinge moved by a treddle. The upward motion is obtained by a spring. At right angles to the knife edge, and

on one side of the machine, an iron arm projects towards the workman. This arm has notches cut into it for the different lengths and breadths of the slates. The other machine is built in the same manner, except that the cutter revolves on an axle something in the manner of an ordinary straw cutting machine.

The old method of dressing slates which is only used in a few localities is this: A block of wood, some three or four feet long, has fastened into one end of it a knife edge, standing vertical, and parallel with the length of the block. The dresser uses a long heavy knife, with a bent handle. He cuts off with the knife two edges of the slate at right angles to each other. Then, with a stick that has a sharp pointed nail in one end and notches cut in it for the different lengths of slate, he marks the other two sides and trims them with the knife. This way requires more skill and is not as rapid as by the machine.

The following table gives the various sizes of slates made and the number of slates that are necessary for a square:

SIZE OF SLATE.	No. of slate to a square.	SIZE OF SLATE.	No. of slate to a square.
24 by 14 inches,	98	14 by 7 inches,	374
24 by 13 "	105	14 by 6 "	436
24 by 12 "	114	12 by 8 "	400
24 by 11 "	124	12 by 7 "	457
24 by 10 "	138	12 by 6 "	570
22 by 13 "	116	12 by 5 "	640
22 by 12 "	126	10 by 8 "	514
22 by 11 "	138	10 by 7 "	588
22 by 10 "	151	10 by 6 "	686
20 by 12 "	141	10 by 5 "	823
20 by 11 "	154	10 by 4 "	1039
20 by 10 "	169	9 by 8 "	600
20 by 9 "	188	9 by 7 "	686
18 by 11 "	174	9 by 6 "	800
18 by 10 "	192	9 by 5 "	960
18 by 9 "	213	9 by 4 "	1200
18 by 8 "	230	8 by 6 "	960
16 by 10 "	222	8 by 5 "	1152
16 by 9 "	246	8 by 4 "	1440
16 by 8 "	277	7 by 5 "	1440
16 by 7 "	316	7 by 4 "	1800
14 by 9 "	300	7 by 3 "	2400
14 by 8 "	327		

School slates are made from the slates that are softer

than the roofing material and with a fine grain. The slates are split in the same manner as the roofing slates; then, with a small circular saw, the edges are turned up; the faces are then smoothed off with a drawing knife and rubbed off with a cloth, using some of the fine dust to rub with. The frames are cut out by saws and put around the slates and pinned or glued together.

At Bangor, Chapman's, Slatington, and at some of the larger quarries, works are established for making sawed and planed stuff out of the slates. They are principally used for paving or tiles, tanks, mantles, billiard tables, etc.

The blocks of slate are first split to about the proper thickness. They then are sawed by means of circular, reciprocating, or hand saws to the proper shape. They then are put on a planing machine. The machine is similar to those used in planing iron, only a broader cutter is used, and the bead is coarser. The machine shaves the slate down to the proper thickness, giving it at the same time a smooth, level face. These plates of slate are then put on a rubbing table and polished off to the required finish. The rubbing table is a round flat piece of cast iron from six to ten feet in diameter, revolving horizontally on a vertical shaft. The block of slate to be polished is placed on top of this revolving plate and held by means of clamps from turning with the plate. Sand is then put on the plate and a stream of water run on it. The revolving plate carries the sand around with it and grinds the block of slate to a smooth surface.

G. Statistics.

The following table is taken from the Slatington News of January 25, 1882.

It gives the shipments of slates from the Slatington region, which comprises the shipping points of Slatington, Walnutport and the stations on the Schuylkill and Lehigh railroad.

The amounts opposite the different names does not give the amount of slate made at each quarry but gives the amount shipped by each consignor. He may and often does buy slate from other quarries than his own. Some of the

names given do not own or work a quarry, simply buying slate and shipping them.

One case of school slates has from 6 to 18 dozen slates in it; average 10 dozen to a case; and weighs on an average 149 pounds.

The roofing slates average four to five squares to a ton.

CONSIGNOR'S NAMES.	Squares of roofing slate.	Cases of shcool slate.	Black-board, cases.
Kuntz & Jacobs,	12,717	. .	23
Caskie & Emach,	12,500	2,414	23
Joel Neff,	8,424		
Kum & Moser,	8,330		
F. M. Hower,	7,022		
The Lock Slate Co.,	5,884	282	
Williams & Jones,	4,785	21	
D. Williams,	4,554	3,556	374
D. McKenna,	4,484	18	213
Columbia Slate Co.,	4,467	. .	4
G. W. Griesemer & Bro.,	4,031		
Blue Vein Slate Co.,	3,478		1
Eagle Slate Co.,	2,504	5,799	
John Paules & Co.,	2,224		
Jas. Hess Co.,	2,053	7	74
E. D. Peters,	2,019		
W. H. Seibert,	1,707	. . . .	103
The Industrial Slate Co.,	925		
Oplinger & Griffith,	822		
R. Henry & Co.,	783		
Ontalaunee Slate Works,	690		
Faust, Heinly & Co.,	572		
G. R. Davis,	543		
Daniel Thomas,	502	1	
Jn. J. Roberts,	468	. .	1
Owen Williams & Co.,	423	1	
Wm. T. Jones & Co.,	418		
D. M. Bertolett,	400		
R. A. Thayer & Co.,	316		
Wm. P. Williams,	250		
Newell Slate Co.,	221		
D. W. Roberts,	220		
Edwin Germin,	215	13	
Samuel Caskie,	210		
Wm. F. Jones,	200		
Giffith Ellis,	195		
L. Campbell,	185		
E. J. Williams,	170		
Bertolet & Baer,	150		
Laurel Hill Slate Co.,	130		
Jacob Gilberg,	115		
E. Weiss,	95		
Bertolett Slate Co.,	80		
J. B. Keimes,	80		
J. Balliet & Co.,	74		
J. S. Saul & Co.,	50		

Hy. J. Roberts,	50		
Standard Slate Co.,	47		
A. W. Lerch,	45	1,783	
Jno. Bower & Co.,	45		
G. A. Gotwald,	45		
E. B. Neff,	45		
Levi Weiley,	45		
Thos. Weiss,	45		
Wm. Benninger,	43		
Levi Custard,	40		
H. L. & G. R. Davis,	40		
D. D. Hughes,	40		
D. & J. Moser,	40		
Jonas German,	40		
Saegersville Slate Co.,	28		
Keever & Lutz,	25		
W. K. Moser,	17		
Guard Slate Co.,	4		
Daniel Paules,	3		
Anonymous,	300		
To teams for country use,	7,541		
By Lehigh canal	133		
Total,	110,000		
Thos. Kane,	. . . .	5,753	341
D. C. Pratt,	. . . .	2,542	1
B. Maurer,	. . . .	2,163	
F. Shenton,	. . . .	1,478	
R. M. McDowell,	. . . .	179	
M. W. Wolf & Co.,	. . . .	22	
W. R. Lawfer,	. . . .	20	
Holden M'f'g Co.,	. . . .	19	
M. H. Eaton,	. . . .	13	
J. Laber,	. . . .	10	
O. D. Thomson,	. . . .	10	
Thomas & Bro.,	. . . .	10	
E. Rauch,	. . . .	6	
A. Crayon & S. Co.,	. . . .	4	
J. B. Lippincott & Co.,	. . . .	4	
A. B. Barnes & Co.,	. . . .	4	
G. D. Case & Co.,	. . . .	2	
Sower, Potts & Co.,	. . . .	2	
J. B. Thomson,	. . . .	2	
L. H. Yeager & Co.,	. . . .	2	
W. G. Reimer,	. . . .	1	
Anonymous,	. . . .	997	
		29,704	
Joseph S. Miller,	. . . .	. . . .	7
H. N. Booz,	. . . .	. . . .	4
R. M. McDowell,	. . . .	. . . .	2
			1,171

	Cases of Mantels.
D. Williams,	44
James Hess & Co.,	24
W. H. Seibert,	2
Williams & Jones,	1
	71

	Mantels, Pieces.
Williams & Jones,	2,704

	Hearths, Cases.
James Hess & Co.,	4
D. McKenna,	2
	6

	Flagging, Cases.
D. Williams,	59
The Lock Slate Co.,	20
W. H. Seibert,	18
Penna. Slate Mantle Works,	12
Caskie & Emach,	7
Williams & Jones,	5
J. Hess & Co.,	2
D. McKenna,	1
Laurel Hill Slate Co.,	1
E. Grevemyer & B.,	1
W. H. Grimes,	1
	127

	Flagging, Pieces.
W. H. Seibert,	9,489
D. Williams,	5,958
Kuntz & Jacobs,	968
Kum & Moser,	65
F. M. Hower,	50
The Soch Slate Company,	43
E. Weiss,	35
Newell Slate Co.,	27
John T. Roberts & Co.,	5
James Hess & Co.,	2
Williams & Jones,	1
	16,643

	Flagging, Cases.
Ontalunee Slate Works,	35¼
The Soch Slate Co.,	5¼
Sagersville Slate Co.,	2
Kuntz & Jacobs,	1
Williams & Jones,	1
Standard Slate Co.,	1
D. M. Bartolett,	1
	46½

	Sawed Slate, Cases.
The Lock Slate Co.,	9
Williams & Jones,	6
	15

	Pencil Slate, Cases.
Williams & Jones,	3

Making a grand total of 29,920 tons of slate.

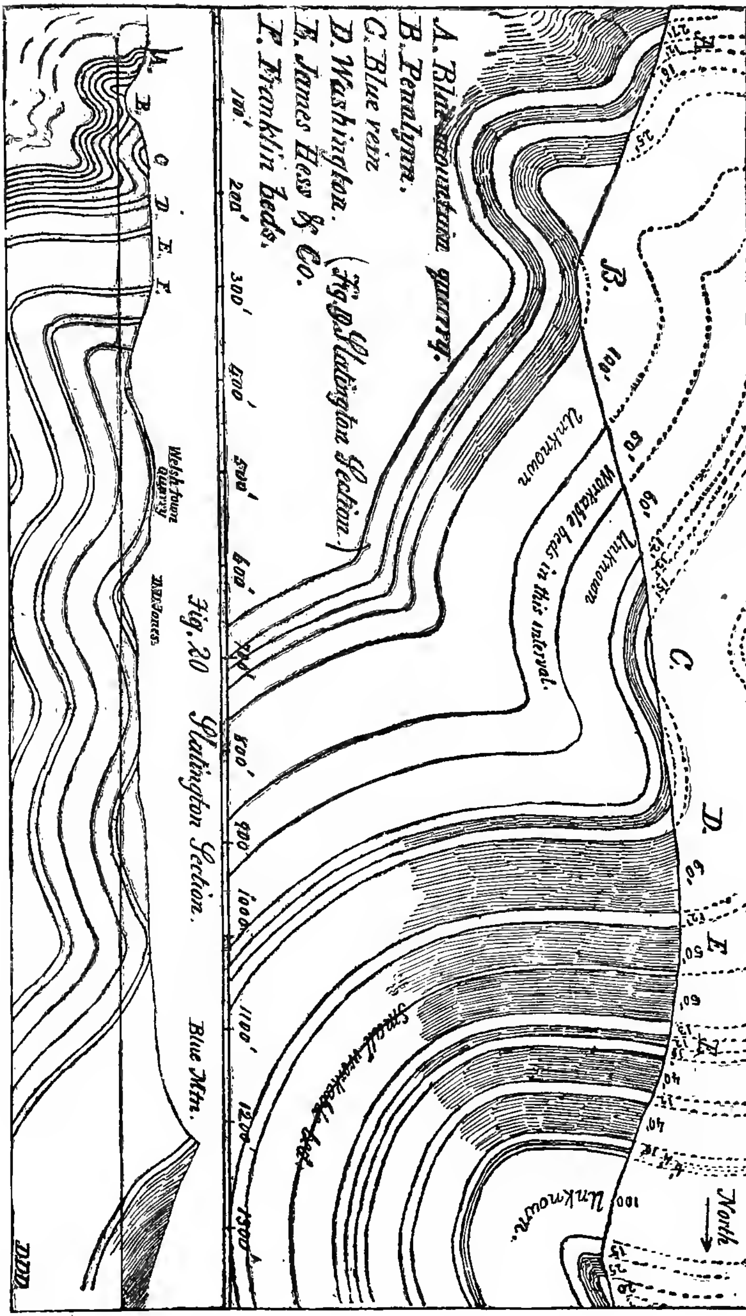


Fig. 20 Slatington Section.

[The discussion of the geological theory of slaty cleavage is reserved, with other matter for the Appendix.

The following notes on the slate quarries in 1874–'5 were not published in the Report of Progress on Pike and Monroe counties, G^6, 1882, although they formed part of Mr. Chance's special report on the Water gaps, which will be found in that volume, because they appertain exclusively to the geology of Northampton and Lehigh counties.—J. P. L.]

The slate quarries in 1875.

With four cross sections.

(By H. M. CHANCE.)

1. The slate belt on the Delaware river.

Throughout the formation the slates have the characteristic dark color of ordinary roofing slate. The thickness of the formation from the escarpment of the Blue mountain to the south end of the measured section (see G^6, page 341) is 2600 feet, south of which are at least 1300 feet more, making at least 3900′.

On the hill side west of D. Bush's house are three openings, abandoned because of the poor quality of the slates; which in the second opening are silicious and ferruginous.

Here I saw traces of organic remains.

In the first opening the silicious slates dip 15°, N. 20° W.

At the Delaware there seems to be but two important beds of slate that yield material of sufficiently good quality to make a good roofing slate. These beds are situated respectively at 1000 feet and 2350 feet below the Oneida conglomerate, (sandrock No. 1.) They are therefore separated by 1350 feet of rock.

Upon the uppermost bed, or bed No. 1, are situated the New York and Delaware River slate quarry and the quarry near the Totts' Gap Road. A small abandoned quarry or opening on the New Jersey side of the river, about half way between the large quarry and the mountain, is on or very near the outcrop of this bed.

The New York and Delaware river slate quarry.—This quarry has a working face of about 40 feet. It has yielded more roofing slate than any other variety although it has a good bed of school slate from 8 to 10 feet thick.

The dip of the slates in this quarry is 20½°, N. 33° W.*

The second bed is 2350 feet below the mountain sandstones and is opened by the John Williams' quarry and the New Jersey quarry.

John Williams' quarry.—This quarry is situated in a very picturesque ravine about one quarter of a mile west of Slateford. It has produced but few school slates, though it has a bed 8 feet thick from which a limited number have been taken. At present (1874) nothing is being taken out but roofing slates.

This quarry has been worked so deep that the water occasions considerable trouble. At the time it was visited (1874) it was partially filled and access was difficult.

The dip of the cleavage planes is very flat (almost horizontal), with the exception of ten or twelve feet of rather harder more sandy slate, in which the cleavage dip is much more inclined.

This is occasioned by the existence of a slide, the direction of which has coincided with that of the bed plates. There is no break, and the plane of the slide is filled by a seam of calcspar from 4 to 12 inches thick.†

By an examination of the section on the Pennsylvania side of the river it will be seen that if the second bed be prolonged it would outcrop about 1000 feet from the southern end of the section; this would bring its outcrop exactly where this slate quarry is situated.

The dip in this quarry is 18° to 20°, N. 35° to 40° W.

The New Jersey quarry.—This quarry is at present in the form of a large excavation, with a narrow entrance used for a tram-way and water-way.

The quarry has however been worked too deep to use

*In nearly all the exposures seen west of the river the slates dip more to the west than upon the east side; the dip on the west side varying from N. 30°—40° W. while upon the east side it *generally* is from N. 20°—30° W.

†This seam is described by Prof. H. D. Rogers, Geol. of Penna., vol. I, page 248.

this entrance with advantage as an outlet for water, and the company has been engaged in constructing a tunnel to replace it. This tunnel is 600 feet long, and will be connected with the quarry by shafts. If this plan was adopted in many other similar instances, as for example at the Lehigh, much annoyance and expense might be saved.

The beds worked in this quarry are identical with those in the John Williams' quarry; the same slide (?) traverses the quarry, the same school slate bed is seen, and the same beds of roofing slate.*

The dip in this quarry is 38°, N. 28° W.

In the factory belonging to this company there is a diamond saw used for sawing out slabs. The foreman of the works states that the diamonds wear more rapidly when working on slates than when sawing sandstone, and that the *finer* the *grain* of the *slate* the *greater* is the *wear upon the diamonds;* and conversely the *more sandy* the *slate* the *less* is the *wear upon them.*

Overlying the slate beds worked by this quarry is a deposit of *glacial gravel* and bowlder drift from ten to twenty-five feet thick. Every year, as the workings were extended, a vast amount of this rubbish had to be removed. By ordinary means this was so expensive that the company was very nearly compelled to stop work. The present foreman has however entirely obviated this difficulty (1874).

At a distance of about a quarter of a mile from the quarry and many feet above its level, a small run has been utilized by means of a dam and flume. The water is conveyed to the quarry through hose and under great pressure directed upon the bank.

Immediately under this bank and around the edge of the quarry a plank trough is built (sluice), into which the gravel is washed and carried off. None but the very largest bowlders refuse to yield to the force of the water.

The original outlay in the cost of construction, hose, etc., was not small, but the saving is very great. The cost of

*In this quarry my attention was called to the fact that the school slate bed immediately overlies a bed of very sandy slate from three to four feet thick. This is probably the case in the John Williams' quarry, although I did not especially observe it.—H. M. C.

removal by the old method averaged from thirty to eighty cents per cubic yard; it is now very trifling, depending, however, upon the amount removed, as it costs but very little more to remove 1000 cubic yards than it does to remove 500 cubic yards.

The Scranton Coal and Iron Company's quarry.—In the lowest part of this quarry there is found an unusually black slate.

A peculiar *overturn* is exposed in this quarry. The normal dip is 32°, N. 75° W., and the overturned dip is 32°, S. 65° E.; showing the flexure to be *rising* as we go *east.* This may possibly be the eastern prolongation of the *offset anticlinal*, which crosses the Blue mountains east of the Wind gap.

Between the limestone brought up by the axis of the anticlinal at Portland and the Kittatinny mountain, an overturn, such as the one above described, is very unusual; at the Lehigh it is characteristic of the structure.

2. *The slate belt on the Lehigh river.*

At the Lehigh Water gap the slate formation wears its usual character of black and blue slates, with an occasional flaggy or sandy member. The upper portion of the mass is well exposed, immediately underlying the Oneida conglomerate, and consists of hard sandy slates, and dark steel-colored fine-grained sandstones, underlaid by soft shaly slates of a bluish black color.

Between this point and Slatington the slates are so twisted and broken that it is impossible to fix the horizon of any particular stratum in the formation. The geological position of the roofing slate bands is therefore indeterminate. But from the general structure we can assert that it is very low in the series, and may belong to the Utica. The roofing slate horizon probably does not include more than ten or twelve beds of good quality, but these are repeated so many times that the impression that there is a much greater number of beds present is given to the casual or even careful observer. The flexures are often so sharp that the dips on both sides of an anticlinal or synclinal are approximately

parallel, and two beds are noted, where in reality but one exists.

The identification and classification of these beds is very difficult, and can only be accomplished by a careful and prolonged study of the subject. A minute examination of the physical character of each bed, and of the number and arrangement of its ribbons, studied in connection with the structural geology, might lead to their systematic arrangement.

Going southward from the mountain towards Slatington but few exposures are seen, and at these the slates are so broken and twisted that it is always difficult, and often impossible to define the structure.

At the junction of the slates with the Oneida conglomerate (No. IV) they are finely exposed and are seen dipping *conformably* beneath the mountain rocks.

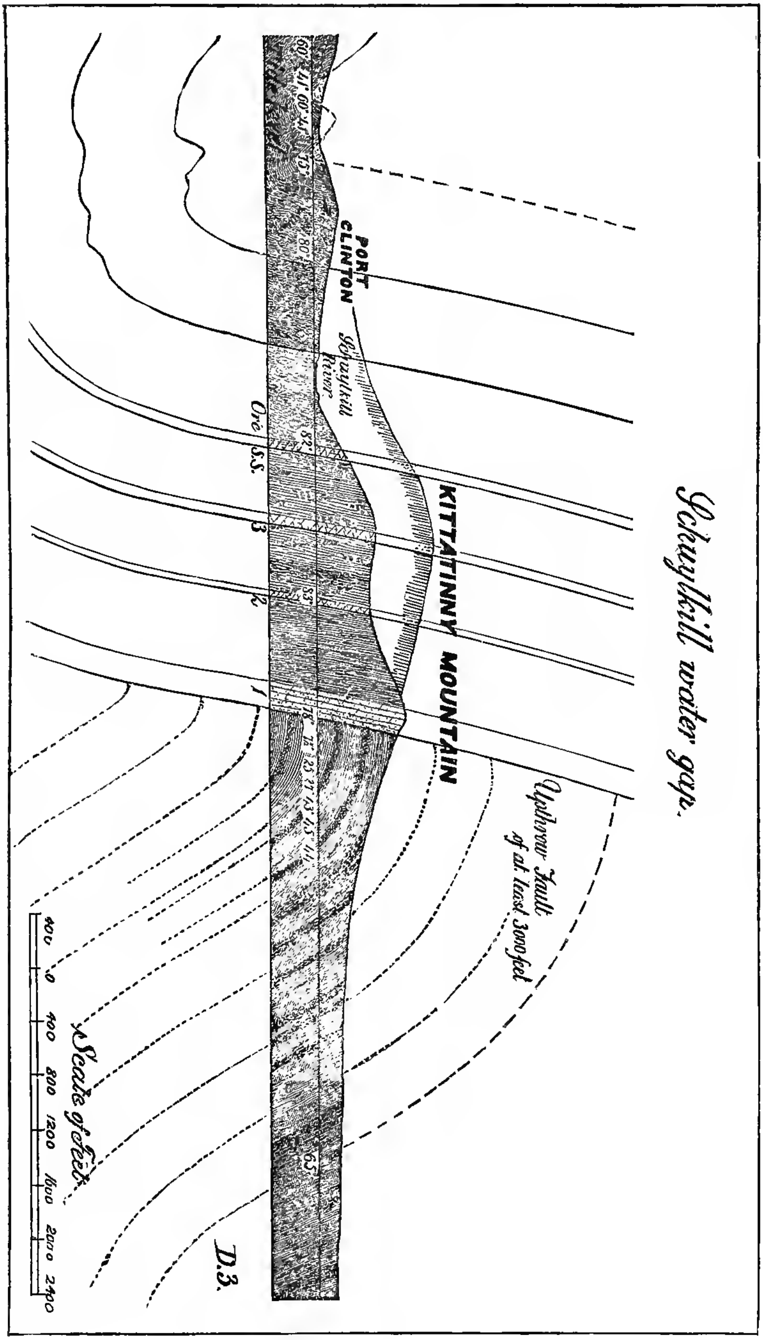
They are here of a very dark color and rather shaly. Some distance south, near where the county road crosses (beneath) the railroad, hard sandstones of a dark steel color predominate, and are finely exposed in a cutting twenty feet high.

Two or three hundred feet further south an *anticlinal roll* is seen with dips of 30°, N. 5° W., and 45°, S. 45° W., which is therefore dying away to the west, and is evidently but a small local disturbance.

From this point southward to the Chain Bridge there are no exposures. From this bridge southward for 320′ a northwest dip prevails, varying from 45° to 30° to 80° N. by W.

We next pass 170 feet with no exposures, and then meet a S. E. dip, which either forms an *anticlinal* or a *fault* with the previous N. W. dip.

The next exposure is at the lock on the L. and S. canal, where a beautiful exposure of a *slip* is presented in a cutting twenty feet high. On the north side of the slip the dip is 23½°, S. 15° E.; upon the south side 41°, S. 30° E. The slates on the south side are harder than those on the north side. The plane of the slip is clean and abrupt and free from dirt, and there is no curling over of the beveled edges, the slide having taken place along one of the bed


Schuylkill water gap.
PORT CLINTON
Schuylkill River
Ore
S.S.
3
2
1
KITTATINNY MOUNTAIN
Upthrow fault of at least 3000 feet
Scale of feet
400 0 400 800 1200 1600 2000 2400
D.3.

plates of the steeper dip. The cleavage upon opposite sides of the slip is nearly if not quite parallel. (See long section for sketch of slip.)

Between this point and Slatington, a distance of about two miles, there is but one reliable exposure, and here the dip observed is 35°, S. by E.

Structure at Slatington.—We have here to deal with three principal flexures, viz: the Washington quarry *anticlinal*, included between the Williams' quarry *synclinal* and the American quarry *synclinal.* And on these flexures only has the horizon of good roofing slate been found.

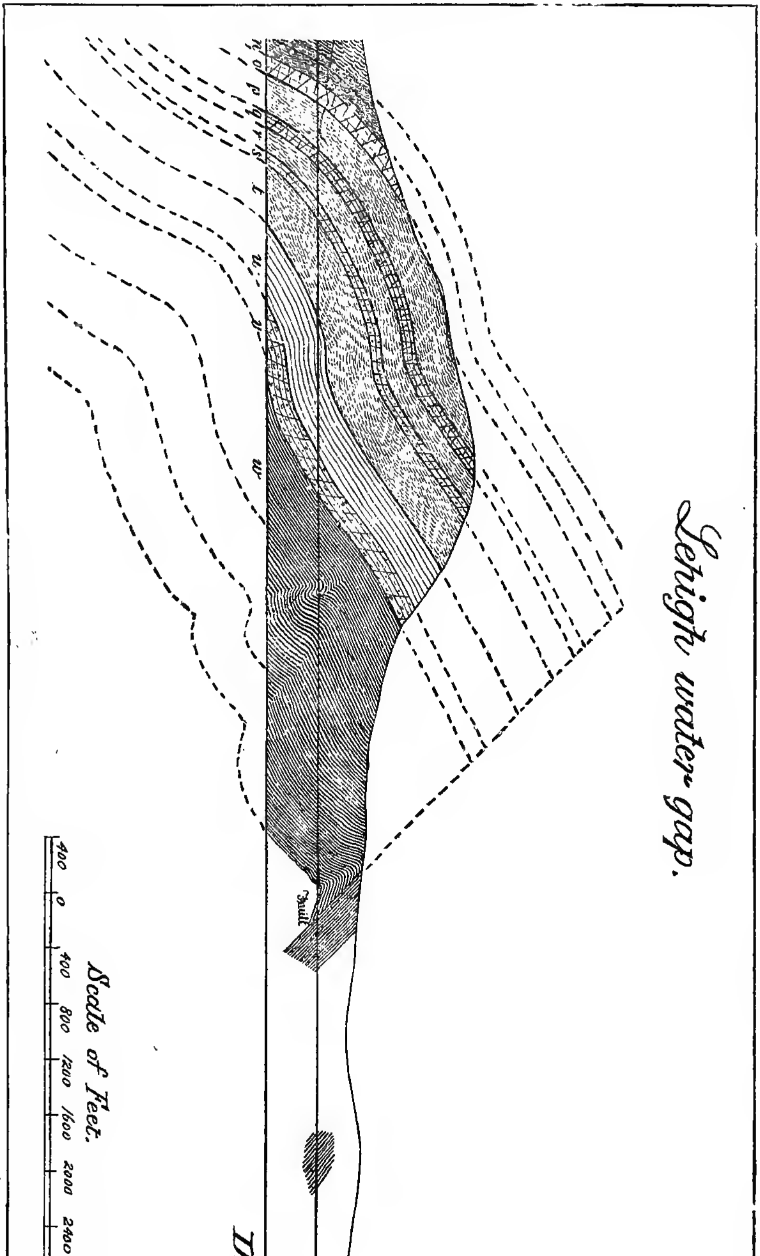
The most northern quarries are situated on dips of the Williams' quarry synclinal; the most southern, on dips of the American quarry synclinal.

The *Williams' quarry synclinal* is seen in Williams' quarry No. 2. It is here overturned with dips of 70°, S. by E. and 25°, S. by E. From this quarry the axis runs westward with a course of S. 87° W., and is next seen in the Bangor No. 2. It is here slightly overturned with dips of 85°, S. by E. and 35°, S. by E. It is difficult to trace the extension of this axis westward, there being a lack of good exposures, but it can be stated with but little probability of error that this axis will be found a short distance north of the Columbia and American No. 1.

The *Washington quarry anticlinal* when first seen appears to be but a sharping of the dip from two to three degrees of inclination to nearly or more than 90°. Eastward it probably dies out. Going westward it is seen at the American quarries. It here carries the beds of American quarry No. 2, into the air and brings them down again in American quarry No. 1. This axis curves gradually from a course of S. 85° W. to S. 67° W., passing just south of the Columbia and American No. 1—where it is a true anticlinal—and about midway between the Girard quarries and Traut Creek quarry, where it is an overturned anticlinal.

It can be seen at an old working east of the Washington quarry, and may be detected along the railroad above the Mantle quarry.

The *American quarry synclinal* is well seen at the



Lehigh water-gap.

American No. 2, and at the Eagle quarry. Eastward it passes but a few feet south of the Blue Vein quarry. Here it can hardly be recognized as a synclinal, being but a gentle curving of the dip from 80°, S. E. in the Eagle to 10°, N. W. in the Blue Vein. Westward it may be found just south of the Traut Creek quarry. It is here a true synclinal.

In this vicinity, besides the main flexures described, there are several other rolls, which do not materially affect the district in which the quarries are situated.

The *Welchtown anticlinal.*—North of the Williams' synclinal, and in the vicinity of the Welchtown quarry, an anticlinal axis traverses the strata, running nearly parallel to the other flexures.

South of the American synclinal, and between it and the Williamstown quarry, it is probable that both an anticlinal and synclinal flexure exist.

Franklin quarries (No. 1).—Opened in 1853. Owned by Jones and Williams.

Contains two beds roofing slate 19 and 27 feet. Product, roofing and flagging slate. At present (1875) some sixty feet below water level. The slates exhibit a gentle roll, but all dip due north.

Traut Creek quarry (No. 4).—Opened in 1865.

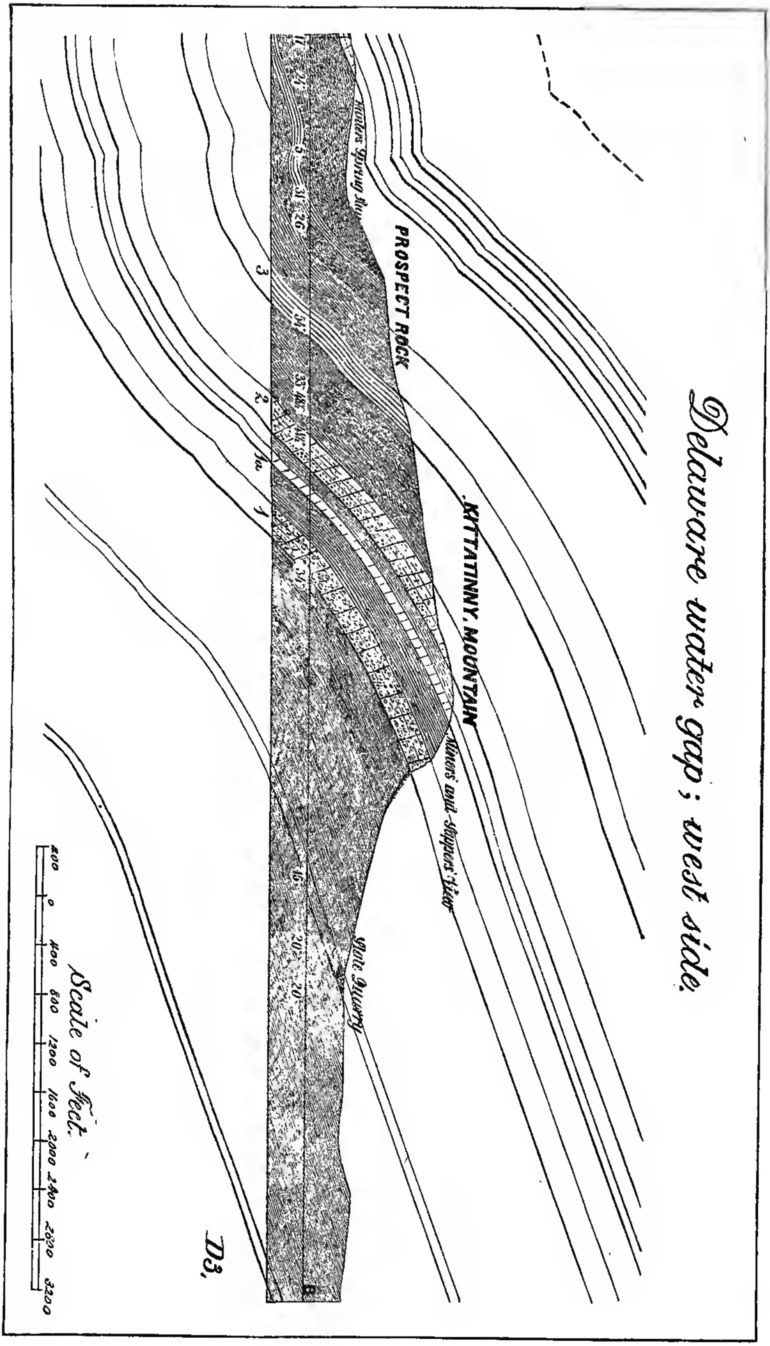
Contains one bed 27′ thick ; dip 58°. About 50 feet deep. Not now worked.

Welchtown quarry and tunnel.—First opened on west side of the river, at Slatington, about 1845 (Davis' quarry). Probably opened on same beds as the Franklin quarry.

Benjamin Kern quarries.—Opened 1868–9. Dip 12°, N. 25° W., in old quarry now abandoned.

Girard quarries (Nos. 2 and 3).—Opened in 1866. Formerly the "McDow." The larger quarry is about 400′ long by 50′ to 80′ wide, and contains one good bed 27′ split. The Washington quarry anticlinal traverses the quarry with dips of 20° to 60°, N. by W., and 73°, S. by E.

The smaller opening is about 200′ long by 50′ to 60′ wide, and contains two beds 23′ and 35′ split respectively, dipping 67°, S. by E. A bed of school slate 7′ split is also found



Delaware water gap; west side.

but is not worked. When visited (1875) both of these quarries were lying idle, and contained much water.

The 27′ and 23′ beds are probably the same with those worked at the Washington quarry.

Williamstown quarry.—Opened about 1847. An irregular excavation about 350 feet long by 100 to 150 feet wide by 125 feet deep. Dip varies from 90° to 0° to 20° to 75°, N. W.

Contains three large beds 23′, 12′ and *23′ split and a 16′ bed on the opposite side of the road. Was in good working order, getting out a large quantity of roofing slates when visited in 1875. Owned by H. Williams, Esq.

Columbia quarry.—Working same beds as American Nos. 1 and 2, viz: two beds. Dip nearly vertical, cleavage 60°±, S. E.

American quarry No. 1.—Working same bed as the No. 2 quarry. The No. 2 quarry is situated on the axis of a *synclinal*, and the No. 1 on the north dip of the *Washington quarry anticlinal*, running between the two openings. Dip N. 15° W., 75°. The bed is about 30′ thick, giving 40′ split.

American quarry No. 2.—Opened about 1870. No school slates, no slabs. 40′ bed roofing slate. Dip slightly overturned on one side of the quarry; nearly flat in bottom of quarry. Strike about N. 82° E. Opening about 300′ long by 100 feet wide and 40 feet deep.

Eagle quarry.—Opened 1866–7. Roofing slates only, two beds 28′ and 36′. In line with American quarry No. 2, and shows the same structure. Strike about N. 75° E.

Blue Vein quarry.—Opened in 1866. Thought to be the same with the Eagle, American and Columbia quarry beds. Dip about 15°, N. 15° W. This quarry is opened on the north dip of the *American quarry synclinal.*

Daniel Jones' quarry.—This is a small opening nearly in line with the above series, and situated on the S. E. side of Traut Creek. Dip 66°, S. E. Filled with water and not working at time of visit.

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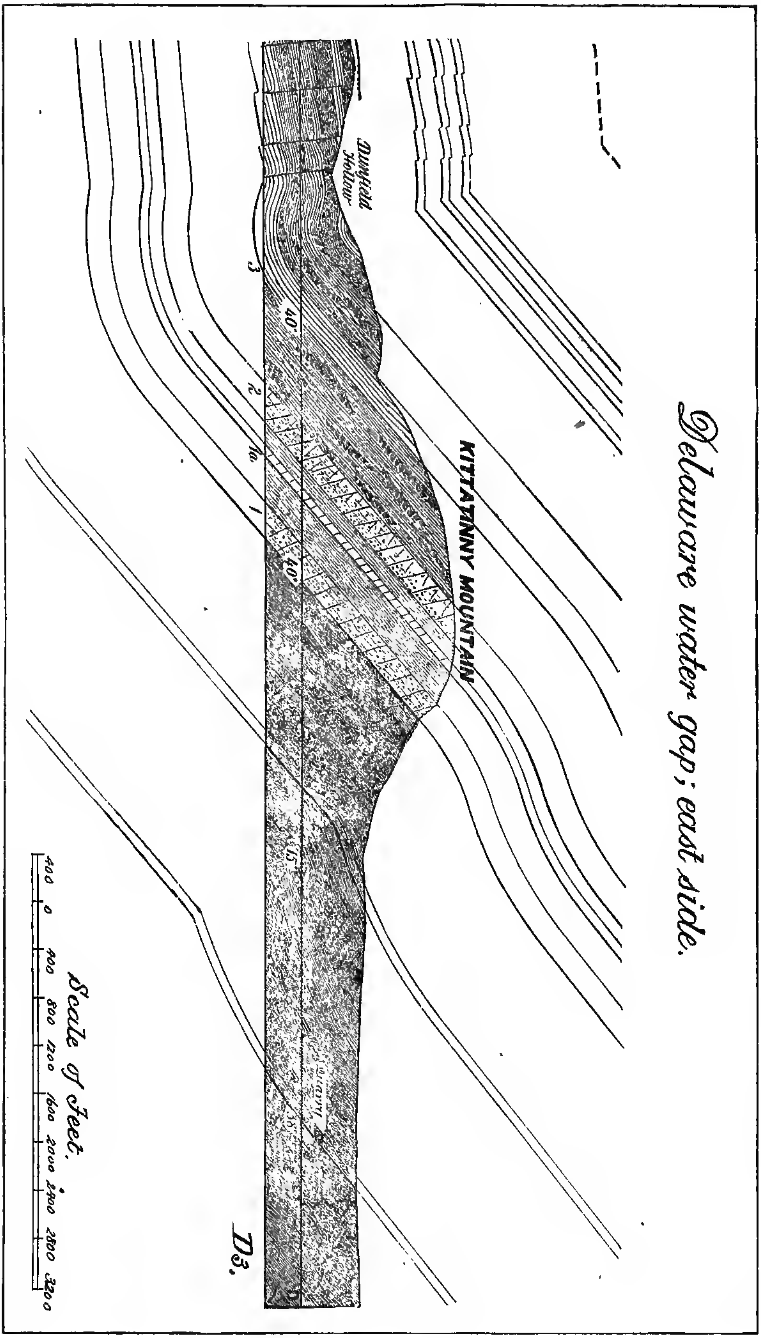
* Not worked.



Delaware water gap; east side.

David Williams' quarry, Nos. 1, 2, and 3.—Quarry No. 1 opened in 1873. Roofing slates only; one bed, 40′ split.

Quarry No. 2 opened about 1845–50. Nothing but roofing slates. This quarry shows the synclinal axis already described at the Williams' quarry synclinal.

Quarry No. 3 opened about 1863–4. Roofing, school and mantel slates. Several school slate beds from 4 to 10 feet split.

These three quarries are situated along the track of the L. V. R. R. just north of the station.

They are situated so close together that an almost continuous exposure of the slates is in sight from the depot to the Keystone quarry. Going north from the station the dip varies thus: 55°, S. 20° E. (No. 1); then 70° S. E. (which is the *north* dip of the synclinal overturned); then 25°, 60°, 0°, S. E., and finally in the Keystone 25° to 30° S. E.

Keystone quarry is about 300 feet north from the Williams' No. 3 quarry.

Bangor, Nos. 1 and 2.—These quarries, with the Heimbach to the north, present the same structure as the Williams' quarries. The *Williams' quarry synclinal* is seen in the Bangor No. 2, with dips of 85°, S. 4½° E. (overturned), and 35°, S.

In the Bangor No. 1, the dip is overturned to the south—85°, S. 4½° E.

Heimbach quarry shows a dip of 35°, S. E.

Washington quarry.—This shows the *Washington quarry anticlinal.* The dip on the crest of the arch is quite flat; its north dip is from 80° to 90°.

This quarry is a large excavation about 400 feet long, and nearly 200 feet wide.

CHAPTER III.

The limestone region.

(BY F. PRIME, JR.)

1. *The geological age of the limestones.*

In Report DD, on Lehigh county, pages 21, 57 and 79, reference is made to the fossils which have been found there, and it was pointed out that while a portion of the limestone was probably of *Chazy* age, another portion was probably *Trenton.*

In Northampton county a few fossils have also been found, which tend to throw a little more light on the question. The first of these were found in a quarry on J. Dech's farm, about one and a quarter miles south-west of Bath, near the road leading to Jacksonville. Here in the north-west portion of the quarry there occurs a form which belongs either to the genus *Maclurea* or *Euomphalus*, which Mr. Hall has not been able to determine as the forms are in a very poor state of preservation. These fossils, like those mentioned of a like character in Lehigh county, are probably of Chazy age.

A short distance to the north-east of the last locality there are some encrinital stems, (on R. Krock's farm, where the limestone dips north-west 10°,) which are of Trenton age, as will be shown a little further on in this chapter.

From this point eastward no fossils were met with until reaching Christian spring, where encrinital stems of the same kind as those just mentioned occur in abundance on Samuel Krock's farm in the upper beds of his quarry.

From this point eastward to about half a mile beyond Nazareth, the limestone and shale exhibit an abundance of encrinital stems wherever weathered; this condition of the

limestone being apparently needed to render the fossils visible.

In J. P. Russ' quarry, south-west of and just outside of Nazareth, in addition to the encrinital stems in the top beds of the quarry, there are a few specimens of *Orthis testudinaria* in the lower ones.

The next locality where fossils were found was on A. Knecht's farm close to the Bushkill creek and nearly a quarter of a mile south-west of Stockertown, encrinital stems, *Chætetes lycoperdon* and *Orthis testudinaria* occurring sparingly.

At Churchville there is a quarry on the main road, opposite the church, which is very instructive. The rocks have a gentle anticlinal roll, as seen on the map. In the upper beds of the quarry there is an abundance of encrinital stems, like those already mentioned, wherever the strata are weathered; but where fresh unaltered limestone occurs these are not so apparent. The lower beds contain a number of specimens of *Leptæna sericea*, *Orthis testudinaria* and *O. pectinella.* This locality is important as proving the *encrinital stems*, and consequently the beds containing them, to be of Trenton age. Hence wherever these encrinital stems are found in Northampton, Lehigh, Berks and other counties west of them we know that the rocks containing them are of *Trenton age.*

On I. Ackerman's farm, about a quarter of a mile east of Keller's tavern, there are two or three outcrops which contain the same encrinital stems.

The last locality where fossils were seen was in the quarries along the Delaware river, south of and close to Howell's cotton-mill. Here *Leptæna sericea*, *Orthis pectinella*, *O. testudinaria*, *Strophomena alternata*, *Chætetes lycoperdon* and one or two unknown forms were observed. In these quarries the fossils apparently lie in colonies of twenty to two hundred individuals, and not scattered indiscriminately through the rocks.

What then are the conclusions to be drawn from the paleontological, stratigraphical and lithological facts stated in the previous pages of this and prior reports?

First. That close to the junction of the limestones and slates we have undoubted evidence of the presence of Trenton limestone.

Second. That whenever the encrinital stems occur, which an examination shows to belong all to one genus, the rocks containing them are either of Trenton or possibly of Hudson river age. The lithological evidence and the close association with the Trenton fossils throw the preponderance of testimony on the side of the *Trenton age.*

Third. There being no evidence or indeed any sign of stratigraphical break in the limestones from the Trenton limestones downward, it must be concluded that the so-called magnesian limestones are of Trenton or still earlier ages. Mr. Hall considers that the specimens of *Euomphalus* or *Maclurea* found in Lehigh and Northampton counties are of *Chazy age.*

Fourth. The lithological evidence, a poor guide, it must be acknowledged, but better than none, tends to show that the limestone on the north flank of the South mountain range, close to the Delaware river, is of *Calciferous age.*

Fifth. The evidence taken as a whole goes to show that the magnesian limestones correspond in age to the Calciferous and Chazy epochs; that we have Trenton limestone; consequently that the slates and shales overlying the limestones must be of *Utica* and *Hudson River age.* There is not a particle of evidence that any of these limestones belong to Huronian* or older epochs; all the facts point the other way.

Sixth. There has been a change in the sediments deposited prior to any during the Trenton epoch; but this is due less to an increased amount of alumina, than to a decreased amount of magnesia. It is only necessary to compare the analysis given in previous reports to be convinced of this fact. The cause of this change is at present unknown. It may be due to alternating dry and wet cycles in which more of one chemical element would have been dissolved than another; or to changes of elevations of somewhat remote portions of the earth's crust. Possibly to

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*** As suggested by Dr. T. Sterry Hunt.**

changes in the river courses which were pouring their contents into the Siluro-Cambrian sea. But such views are at present mere speculations, not even worthy to be called hypotheses, and consequently foreign to this report.

2. *The Trenton Limestone.*

The Trenton limestone occurs in Northampton county, along the contact of the Siluro-Cambrian limestones with the Utica and Hudson River shales and slates.

In passing northward from the Lehigh river the limestones, as they approach the junction line of the two formations, become less magnesian in composition, and consequently the relative amounts of lime and alumina they contain increase. The result of this is the occurrence of a hydraulic limestone, which, while worked more extensively on the west bank of the Lehigh River at Copley, may also be traced in Northampton county more or less continuously all the way along the road leading from Siegfried's Bridge to Nazareth; and again in the neighborhood of the village of Martin's Creek.

This limestone has been considered as forming a part of the Trenton limestone, more from its stratigraphical position than anything else, since no fossils occur in it.

Two companies, as mentioned in Report DD, have tried to utilize the hydraulic properties of this limestone in Northampton county, but neither of them have done much of anything in the last four or five years, and every time the quarries have been visited by members of the present geological survey they have been found standing unworked. These companies are "The Old Lehigh Cement Works" and "The Allen Cement Company."

It must not be supposed that because these companies have been apparently unsuccessful, that there is no future in the business of manufacturing hydraulic cement in this part of the State; on the contrary the success of the Copley Cement Company shows what perseverance under difficulties can and does accomplish. Of course the composition of some of the cement-stone beds is far more favorable to the manufacture of cement than that of others, but all may

be more or less profitably utilized for careful intermixture. There is no reason why the manufacture of hydraulic and Portland cements should not be slowly and surely extended, not only rendering this portion of the State free from foreign competitors, but actually rivaling these in many of the western markets on account of the excellence of the product and the cheapness of freights.

These *hydraulic limestones*, however, furnish but a small part of the evidence of the occurrence of rocks of Trenton age; the proofs to be cited are far more convincing.

At Christian spring and at all the localities between it and Nazareth *encrinital stems* like those found in Lehigh county occur in greater or less abundance, the limestone generally appearing to be of a shaly nature.

To the west of the borough of Nazareth there is a large quarry having a north-west dip of 45°. A portion of the beds composing it are *brecciated;* the upper layers contain an abandance of encrinital stems, while in the lower ones there are traces of shells resembling *Orthis*, thus showing the rocks to be of Trenton age.

In the quarries having north-west and north-east dips, just east of the lower portion of the borough, there is an abundance of encrinital stems, showing that the limestone is of Trenton age; and many of the outcrops are composed of hydraulic limestone.

The quarry to the right on entering Nazareth consists of hydraulic limestone.

Following the road from Stockertown to Seips, where it approaches the Bushkill, several north dips may be seen between it and the creek. At this point fossils have been found, to be mentioned later.

At the junction of this road with the Nazareth-Stockertown road, the limestone is shaly and more or less hydraulic in character. The limestone outcrop between Stockertown and Churchville is of the same character.

At Churchville there is a quarry which is particularly worthy of notice. The limestone of Trenton age forms a low anticlinal in the upper beds of the quarry. Where weathered, there is an abundance of encrinital stems, while

the lower strata are full of *Orthis testudinaria* and other allied brachyopods peculiar to the Trenton limestone. Where fresh the rock is of a dark blue, and of a dull and massive appearance.

Following the Nazareth-Martin's creek road there is a quarry a short distance beyond Keller's tavern having an easterly dip. In this, as in the two other outcrops close to it, the limestone of a dull, somewhat earthy, appearance contains encrinital stems.

Just beyond Mud run the road ascends a steep hill, composed of shaly limestone, colored black by the presence of a large quantity of carbon, and the outcrops of this character continue all the way to the village of Martin's Creek. This limestone is erroneously described in the Geology of Pennsylvania, Vol. I, page 239, 1858, thus:—

"On Martin's Creek the passage from the limestone to the slate formations exposes at least 300 feet thickness of the *Utica black slate* without fossils, and from 300 to 400 feet thickness of fossiliferous *Trenton* limestone, all dipping at 30° on an average to N. 30° W., and all thoroughly cut up by cleavage-planes, which, for the most part, are almost absolutely horizontal, except where they curve in a sort of waving or sigmoid bending between the planes of bedding.

"In the Trenton limestone are to be found *Chætetes Lycoperdon*, and two or three other characteristic well-known points of the formation.

"Beneath this argillaceous Trenton limestone may be seen, in the first anticlinal south of the boundary of the limestone and slate, the smooth, massive marble beds visible on the Mohawk, and characteristic of the higher members of the Auroral series."

Returning south, along the Delaware River road, Trenton limestone, containing fossils, is seen in the quarries between Howell's cotton-mill and Mud Run.

3. *The Magnesian Limestone.*

This group includes the *Trenton*, *Black River*, *Birds*

eye, *Chazy*, and *Calciferous sandstone* limestones of the New York geologists.

In other Reports of the Second Geological Survey of Pennsylvania the term *Siluro-Cambrian* limestones is frequently used. They correspond to the *Lower Silurian* of Murchison and the geological survey of Great Britain and Ireland; and to the *Upper Cambrian* of Sedgwick.

As in Pennsylvania it has been impossible to distinguish the different ages of the limestones underlying the Trenton limestone, owing to the great dearth of fossils, it has become necessary to use some common name which should include all of them; and none more appropriate could be suggested than that of *Magnesian limestone*, which, first used by western geologists for rocks of the same age, was afterwards adopted by the New Jersey Geological Survey. By *Magnesian limestone*, however, is understood only the Black River, Birdseye, Chazy, and Calciferous limestones; because the *Trenton* limestone is practically non-magnesian in the eastern parts of the United States.

If we pass southwardly from the Kittatinny mountain over Northampton county, the first limestone met with is at Portland. It here forms an anticlinal wedge about one and an eighth miles long on the Delaware and extending back about two miles to Long's farm, where the last of it is seen. Its southern limit is quite distinctly defined, and the limestone is seen to pass *conformably* under the Hudson River slates (No. III.) The limestone which crops out seems to belong both to the Magnesian limestone and Trenton periods. The reason for this supposition is that the lower beds, which are extensively worked by Luther Keller, closely resemble lithologically those of the Magnesian limestone in the southern part of the county, and contain no fossils; while at John I. Miller's quarry, one third of a mile south-east, where the limestone excavated belongs to higher beds, the same *crinoidal stems* occur which have been found elsewhere in the county in rocks considered, for reasons already stated, to be of Trenton age.

At both the quarries the limestone has a south-east dip

and passes conformably under the slates as above stated. When, however, we come to trace its northern border this can only be done approximately on account of the *glacial moraine* which covers over and conceals the limestone. By following the river road from Portland to the Delaware Water Gap obscure traces of the limestone were once or twice found as far as the road leading down to the river at the public school, while a little to the north the slate hills make themselves apparent. Going west, limestone is last seen in an old and almost obliterated quarry on Long's farm.

This small area of limestone on the Pennsylvania side of the Delaware is the commencement of a narrow limestone basin which extends into New Jersey for a distance of twenty-five miles to Branchville in Sussex county. Its position and general direction seem to indicate that its upthrow through and exposure among the slates is in some way connected with the Offset Knob in the Kittatinny Mountain, east of the Wind Gap, the connection of the two being at present obscure and only to be determined by an instrumental survey.

On the west side of Northampton county there occur two limestone areas, one between Kreidersville and Seemsville, the other east of the latter village, which are very probably in reality one continuous area, the connection being concealed by drift and soil. Here too the limestone is *conformable* with the overlying Hudson river (No. III) slates. The outcrops are patches separated from the main body of the limestones by a narrow belt of the slates.

The north border of the main body of limestone commences about half a mile north of Siegfried's bridge and continues nearly due east until it reaches a point a little south-west of Bath. Here it makes a northward bend of about a mile and passing through Bath it continues with a zig-zag border almost due east to Nazareth. At the latter point it bends toward the north-east and continues in this direction through the village of Martin's Creek and then extends as a strip about half a mile wide parallel to the Delaware river as far

as Belvedere; here leaving Pennsylvania and crossing into New Jersey it extends to a little beyond Butzville in Warren county.

The southern limit usually outlines the northern border of the South Mountains, except at Bethlehem, where it continues south through a break in the mountains and forms the Saucon Valley basin.

Rogers in his Final Report of the First Geological Survey says* that the *Calciferous sandrock* occurs "about 60 feet thick at Easton and that its characteristics are a coarse grey calcareous sandstone, containing drusy cavities, enclosing crystals of quartz and calc spar." Again † "The Auroral calcareous sandstone occur as a thin formation in the vicinity of the Delaware, presenting very nearly the type which it exhibits under the name of Calciferous sandstone in New York. It seems not to have been everywhere deposited, for we meet with only occasional indications of it further towards the S. W. along the valley."

Careful searches for this formation have been made near Easton both along the South Mountain, as well as along Chestnut Hill, and but one trace of it has been found which would distinguish it from the ordinary Magnesian limestone. This point is on the Delaware river about one and a half miles south-east of Easton. Here, on the river road, close to the junction with the Laurentian rocks there is a coarse sandstone having a S. E. dip of 32°.which gradually passes into a limestone full of quartz grains; above this at an interval of 15 feet is the ordinary limestone. This has not been observed at any other locality.

An examination of the accompanying map shows the limestone lying *conformably* over the Potsdam Sandstone along the flank of the South Mountain between Allentown and Bethlehem: the general dip of the limestone is northwest and the amount of dip not over 25°.

At South Bethlehem the ridge of Laurentian rocks which has formed the approximate boundary of the Lehigh abruptly ceases, subsiding beneath the limestone. The latter

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* Vol. I, p. 105.

† Vol. I, p. 238.

consequently folds around the eastern end of this ridge and is met with at several points on *Fountain Hill* generally dipping about S. 82° E., and having a gentle dip of 16° or thereabouts. Having thus folded around and passed under a covering of soil across the valley leading to *Lechauweki Springs* it again becomes visible along the northern flank of the mountain on which Lehigh University is built, having a general north-west dip and overlying the Potsdam sandstone *conformably* wherever the latter is exposed. Passing east the beds in the quarry of the Bethlehem Iron Company have a north-east dip showing the limestone to be bending around the end of the ridge, south of Bethlehem.

The limestone passes south, through the break in the Laurentian rocks, between Bethlehem and Shimersville, in the Saucon valley, and is seen close to the abandoned branch of the North Pennsylvania railroad having a dip of 12° to the south-east.

South of the Laurentian ridge, terminating south of furnace No. 3 of the Bethlehem Iron Company, the limestone reappears on the road from Shimersville to Seidersville, where it is seen, in a quarry on the road, to dip S. 50°, W. 23°, dipping away from the Laurentian rocks a few hundred feet to the north. This synclinal, which is seen commencing here, can be traced east to the North Pennsylvania railroad track, the limestone at the latter point dipping 22° in the same direction, after which it is concealed by glacial Drift.

To the east the limestone occurs forming a small bay up the Laurentian valleys south-east of Shimersville, but no reliable dips could be obtained.

At Shimersville the Laurentian rocks come down to the Lehigh cutting off the limestone; but about half a mile north-east the latter reappears at the quarries on the railroad. Here the first dip is S. 23°, E. 45°, and this same direction of dip is visible about three quarters of a mile farther east, the limestone dipping S. 31°, E. 48°. At the former locality the limestone is thickly bedded, the beds becoming thinner towards the top; it is gray and compact, with sometimes a tinge of blue; some of the beds contain

a little intercalated hydromica slate. At the latter locality the limestone is blue and massive with a north-west cleavage.

The other side of the *synclinal* formed by these dips is nowhere to be seen, being covered by the soil and *débris* which has fallen from the mountain ridge to the south.

Close to the quarries just mentioned an *anticlinal* occurs indicated by the limestone dipping 21°, N. 33° W. At this outcrop the rock is bluish, compact, and thickly bedded; it contains an abundance of small cavities, for the most part filled up with calcite, and there is a good deal of pyrite disseminated through it, more or less altered to limonite. Thirty feet east of the lime-kilns the limestone becomes very hydromicaceous, but it was impossible to ascertain the dip.

Following the Lehigh Valley railroad east, the Laurentian rocks cut off the limestone once more before reaching Redington, but this only for a short interval, when the latter rock reappears having a varying south-west dip as seen on the map. It contains much flint and thin beds of hydromica.

The dip soon changes again to the south-east, and the little creek running into the Lehigh between the two last dips seems to be in a limestone trough. At this south-east dip thick massive beds alternate with thin shaly ones; the limestone is compact and blue to dove-colored.

At Redington there is a sharp *anticlinal* forming a prominent feature at that point. The limestone is compact, dark blue, thickly bedded and, in places, semi-crystalline.

From Redington to Chain Dam the limestone has a north-west dip wherever observed. At the latter point there is again a change to the south-east, and between Chain Dam and Glendon there is an *anticlinal* formed by the Laurentian ridge which terminates a little to the east. Back of this ridge the limestone follows up a ravine of Laurentian rocks for a little distance, stopping, however, before meeting the Old Philadelphia road.

On the Lehigh Valley railroad track the brief north-west dip, forming the anticlinal, ceases opposite the store-house

of the Glendon Iron Company and the normal south-east dip again prevails. But passing to the Delaware, where the most southerly dips again appear, we find the limestone nearest to the Potsdam sandstone at this point to have a north-west dip for a short distance north of Morgan's hill, which changes at a slight ravine to a south-east one and retains this all the way to the Lehigh river on the north.

If the strike of the limestones along the course of the Lehigh is noticed it will be seen that where the river makes its easterly bend at Allentown the limestones have a general northern dip. This seems to have been occasioned either by the mass of Laurentian rocks to the south of the river or else by the smaller uplift of the same rocks which occurs close to the north-east, and which subsides beneath these limestones.

Along the river from this point to Freemansburg the limestone outcrops along the northern bank have a general northern dip.

Sandstone.—Just west of the round-house of the Lehigh and Susquehanna railroad at Bethlehem there is a cut on the track. In this cut there occurs a *sandstone* bed nineteen inches thick, conformably interstratified with the limestones. The lower nine inches of this bed are a pure *quartzite*, while the upper ten inches are more of a conglomeratic and contain more or less limestone intermingled with the quartz. It is possible that this is the same sandstone* which has been noted as occurring near Trexlertown and Breinigsville in Lehigh county, in which case it has thickened considerably in the interval. It must be remarked, however, that it has nowhere been observed to occur between the two localities.

At Freemansburg a sudden change in the direction of the dip takes place, produced by the upthrow of the Laurentian ridge south of the river; and an *anticlinal* is formed in the hill cut through by the Lehigh and Susquehanna railroad, which is a continuation of the one on the east side of the river.

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*See Report of Geological Survey on Lehigh County for 1874, p. 34 and 36.

Between Gwinner's Island and Redington there is an *anticlinal* along the northern bank of the river; the beds dipping north-west increase the amount of their dip suddenly as they approach those dipping south-east, and at the point of junction there is either a fault or else an exceedingly steep fold, most probably the latter, as it corresponds in position to the one at Redington east of the Lehigh.

West of Hope's station there is another *anticlinal* along the railroad track, which continues to limestone quarry west of Glendon and extends to a point due north of the Glendon Iron Works. From this point eastward the dips are almost south until close to the station of the Lehigh and Susquehanna railroad at Easton, where a pronouced south-west dip is met with, possibly due to the elevation of Laurentian rocks at Mount Ida in Phillipsburg.

Returning to the western edge of the map we see that limestone occurs east of Allentown and west and north of the Laurentian rocks. Those dips which are closest to the Potsdam sandstone are conformable in dip to this; but just beyond, a local *synclinal* followed by an *anticlinal* can be seen. This is doubtless due to the folds occasioned by the uprising of the Laurentian rocks. That portion of the limestone at this locality nearest the river is frequently brecciated; but a short distance to the eastward it becomes sandy; while at the eastern-most lime-kilns it is dark blue, massive and often vitreous.

These are the last limestone outcrops visible for some distance, as the drift conceals the outcrops. The next that are seen are north-east of Rittersville and north of the eastern end of the Laurentian hill where the limestones have a general southerly dip and are dark blue, massively bedded and more or less crystalline in character. This south-east dip continues to Bethlehem, where on the Nazareth turnpike, just north of the borough limits, a small *anticlinal* is indicated.

On Nancy run about 800 feet north of the Lehigh there is a synclinal, the bottom of which is seen and which is only a local roll.

West of Wagnertown there are two northern dips, the

most western of which is a gray crystalline limestone; while the one nearest the village is *oölitic* and appears to contain indistinct *fucoidal* stems filled with sand. North of Hopes there is a north-east dip of a light blue crystalline limestone.

Just east of Mine No. 26 there are two north-west dips of a dark blue crystalline limestone, but the amount of dip is so small that these are probably but local rolls.

On the road from Catasauqua to Shoenersville we have the two quarries showing the collapsed or overturned *anticlinals* illustrated in Report of Progress in Lehigh county 1875–6.

Just north of Catasauqua there is a decided *anticlinal* on Catasauqua creek, which is apparently the expiration of an anticlinal coming from Lehigh county.

About two-thirds of a mile southeast of Shoenersville, on the road leading from that village to Bethlehem, there is a local *synclinal* formed in intercalated damourite slate.

On the Bethlehem-Nazareth road there is a north-west dip seven eighths of a mile north-east of Quaker Hill, and a north-east dip a little to the west of the first.

At Hecktown there are several north-east dips. On the Bushkill, about five-eighths of a mile above where it cuts through Chestnut Hill, there is an *anticlinal* structure, to which the bend of the stream at that point is due. This anticlinal continues to the Delaware river, being at one point overturned and giving a local south-east dip. About a quarter of a mile south-east of Mine No. 4, there is a north-west dip. Half a mile east of Mine No. 2 an anticlinal structure commences, which continues through Smoketown and can be followed almost to Mine No. 12, to which the north-west dip at Newburg is probably related.

We also have the north-west dips on the Easton-Stockertown road, about three miles from the former town.

Finally we have the *synclinal* which commences on the Lehigh between Siegfrieds Bridge and Stemton, passes through Howertown and continues, with intervals, rather near to the junction of the limestones (No. II) with the slates (No. III.)

Attention has been especially drawn to these north-west

dips as showing that *all* the dips are not to the south-east. This has been done in order to show the truth of the law first laid down by Henry D. Rogers that in the Kittatinny Valley the flexures in the strata are folded and the prevalent dip is to the south-east. Rogers * divides the waves into which strata are folded into "symmetrical, normal and folded flexures." "The first is that of a convex or concave wave, or, in technical geological language, an anticlinal or synclinal flexure, in which the two slopes of the wave are equal in their degree of incurvation or steepness." Normal flexures "display an excess of incurvation or steepness of flexure, on one side compared with the other." Folded flexures are those "in which there is an inversion or doubling under of the steeper side of each convex curve or wave; when this structure is at a maximum, the folding back, downwards, of each convex or anticlinal arch amounts almost to a parallelism of the two branches or sides of the curve; and where there are several such foldings, alternately convex and concave, the strata may be said to be crimped or plicated into one dip, though the entire change of direction through which the inverted portions have been bent, amounts to the supplement of the angle of the dip or the difference between the apparent dip and 180°. It is a necessary feature of all such folded flexures, that the approximately parallel sides of the folds dip obliquely and not perpendicularly to the horizon; they are, therefore, but exaggerated instances of the class of normal flexures. The Kittatinny or Great Valley is full of flexures of this extreme type, imparting a prevailing south-east dip to the whole outcrop."

If we look at the Northampton county map accompanying this report, it will be seen that many of the north-west dips, above water, are included between south-east ones, and that in such instances the north-west dips are usually very steep. This but exemplifies the fact that we are dealing with true waves or billows, frozen as it were while in the act of breaking. In places the crest of the billow has

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* See the Geology of Pennsylvania, Vol. II, p. 888 *et seq.*

curled over on itself, giving us uniform south-east dips for both sides of the anticlinal, while at other points it has been arrested in the act of breaking, thus affording local steep north-west dips, the crest-line declining in a gentle curve towards each extremity.

These waves have received their impulse from the south-east and were caused by the upthrow of the South mountain range, which in its upheaval and rise occasioned the contortions by which the Appalachians were formed, for the reader must bear in mind that the Laurentian rocks, which form the mountains known as the South mountain range in Pennsylvania, are a part of the great range which, known as the Highlands in New York and the Blue ridge and Blue mountains in the south, extends from Alabama to New England. Consequently, when this long range of mountains and hills was upheaved the force it exerted on the rock-strata on each side of it must have been enormous. While the rocks which lay to the south-east have been in a great measure eroded or concealed by the later Mesozoic, Cretaceous and Tertiary formations, those to the north-west exhibit in a grand and majestic manner what the force of this upheaval must have been, for the mountains have been thrown up in parallel ranges across the State, all the way to the Great Lakes on the north.

Character of the limestone rocks.

Let us now consider a little more in detail the character of the limestone rocks in the district included in the map.

The limestone is exposed at intervals along the Lehigh Valley railroad track between Allentown and South Bethlehem, its character whenever seen being a blue, semi-crystalline rock, in places much dissolved and containing veins and bands of *calcite* in the cracks. The same may be said of the limestone exposed in that portion of the Saucon valley shown on the map.

Along the Lehigh Valley railroad between Freemansburg and Easton, the limestone sometimes retains the characters described; at others it is more of a light dove color and

earthy or compact. Rarely there are thin beds of *hydromica slate* intercalated in the limestone.

About half a mile west of Mine No. 50, *damourite* containing a great deal of carbonate of lime alternates with a rotten earthy limestone.

On the Delaware at the extreme eastern edge of Morgan's Hill there is a coarse sandstone which gradually turns into a semi-crystalline limestone containing quartz grains; and above this at an interval of 15 feet ordinary semi-crystalline limestone. This is probably the Calciferous sand rock of the New York geologists. A few hundred feet to the north of the last locality occurs limestone overlying the Potsdam sandstone, which is the ordinary blue semi-crystalline limestone. On the road which leads from the school-house on the Delaware to the mines along the base of Morgan's Hill, limestone occurs at the first turn in the road; which contains *hydromica.* Following up the river road the first quarries met with contain *oölitic* beds, while others are *breccias.* At the second quarry there are layers of *brown hematite*, about the thickness of a knife-blade interstratified with the limestone. Four hundred feet further north the limestone is compact and solid to shaly and decomposed.

In the nearest quarry but one to the brewery there occurs a bed of *sandstone* 5 inches thick, inter-bedded in the limestone. The strata have a south-east dip at this point which is probably but a local crimple and which may be in part due to the action of Mount Ida in Phillipsburg.

In the quarry nearest the brewery there again occurs a bed of *sandstone* 5 to 8 inches thick, and there are also thin beds of *damourite*-slate and an *oölitic* bed all interstratified with the ordinary limestone. The south-east cleavage forming an angle with the bedding was very prominent at the time the quarry was visited. One of the limestone beds one and a half feet thick is compact, shaly and black, the latter due to the presence of carbonaceous matter. Comparing the sandstone bed with that in the previous quarry just mentioned from their thickness it was at first thought they might be identical; but if this is the case there has been either a fault or a sharp fold between the two exposures.

As there is no evidence of either of these having occurred, it seems more probable that there are two thin beds of sandstone interstratified with the limestone. It may possibly be the case that one of them is the same as that observed near the round-house of the Lehigh and Susquehanna railroad at Bethlehem, but it is more probable that they are local deposits.*

The limestone in Mount Parnassus, through a cut in which the railroads pass to cross the Delaware, is the ordinary kind varying from semi-crystalline to compact and in some cases earthy varieties.

At the west end of Morgan's Hill limestone crops out very near to the gneiss, so close indeed that there is apparently no space between for the Potsdam sandstone, and it is very likely the latter rock was not deposited at this point.

In the two limestone valleys on the Delaware which are inclosed in the Laurentian rocks, the character of the limestone is blue to dove-colored, and varies from semi-crystalline to compact in texture.

The limestone knob at the High School in the town of Easton is of the semi-crystalline, blue variety.

On the road leading up College Hill the limestone is of the blue, semi-crystalline sort, containing thin partings of *damourite* slate, and the character of the limestone along the road on Bushkill creek, south of Chestnut Hill, is the same.

On A. Herster's farm, in Palmer township, the limestone is a dark-blue semi-crystalline variety.

Due south of this a more compact sort crops out near the school-house.

South-west of the school-house there is a dark-blue sub-crystalline limestone outcrop, dipping north-west, a little north of the lower Bethlehem road; while south-east of and very near to this there is *oölitic* limestone.

Close to the lower Bethlehem road and between it and

[* In the interior valleys of Pennsylvania, thick massive and persistent sandstone strata lie at various horizons in the great mass of the Siluro-Cambrian magnesian limestones. In Missouri they form members of the system of equal value with the limestone members.—J. P. L.]

Mine No. 26. there is a limestone outcrop, having a south-west dip, which is compact, of a dove-color, and weathers sandy. On the same road, about two miles east of Wagnertown, a siliceous, dove-colored limestone occurs, having a south-east dip.

On the road which leads to Hope's Station there is a light-blue sub-crystalline limestone.

Just west of Wagnertown is an *oölitic* variety of the same rock, containing forms which resemble *fucoidal* stems filled with sand. Just north of the same road and close to Nancy's Run, are two south-east outcrops of blue, massive limestone, the upper beds being shaly and fawn-colored.

Passing up Nancy's Run in a quarry near Butztown there occurs a shaly limestone in the top, which contains a great deal of *damourite*, about five feet thick.

Returning to Easton by the upper Bethlehem road an *oölitic bed* can be observed in the top of each of the three quarries south-west of Farmersville, which have a south and south-west dip, while the outcrop having a south-east dip is composed of shaly limestone. North of this last the rock is thinly bedded and a blue, sub-crystalline variety close to the road. The same can be said of the outcrop in the village itself.

The two outcrops to the west of the road which leads from Farmersville to Mine No. 19, consist of a variety which apparently weathers readily and crumbles to pieces in the fingers; while that east of the road is a massive, dark blue, semi-crystalline rock, the upper beds of which are more thickly bedded than the lower ones.

Returning to the upper Bethlehem road, there is a blue, semi-crystaline limestone, having a south-west dip, which contains *quartz veins* and bands through it. While the outcrop, just to the east, while having the same appearance, weathers readily to a sandy rock.

A little to the west of mine No. 26 occur loose blocks and fragments of the black *flint*, so common in the limestone.

On P. Hays' farm, in Palmer township, near Seips', there occurs a compact light colored limestone, full of cracks,

filled with indurated clay. In the limestone outcrops just west of Seips' there occurs a great deal of *damourite* slate interstratified with it, while the limestone is of a shaly more or less thinly bedded variety.

On the hill just north of Seips' there occurs on the Nazareth road a blue limestone containing crystalized quartz, and thin sheets of *damourite* slate. West of this outcrop limestone bowlders occur in the field, containing *encrinital* stems and casts of *brachyopods.*

Branching off on the road from Seip's to Stockertown the limestone outcrops met with are of a slaty variety. Still further north on A. Transue's land the outcrops are dark blue and semi-crystalline, while the rock is crimpled so as to be almost horizontal in places.

Following the road south of Churchville the limestone is seen to be horizontal at the cross-roads; while to the west there is an anticlinal structure. The limestone, at these latter points, is bluish-grey and full of small spots of white calcite, once probably *fossils.*

Following the road to the west crystalline black calcite is seen in the quarry close to the Bushkill.

Following the Bushkill towards its mouth, the limestone observed is of the ordinary bluish-grey semi-crystalline variety, and there is nothing to claim ones particular notice until reaching a point where the rock has a south-west dip of 24°. Here the limestone is thickly bedded; while just north of it and close to the road the limestone is seen to be thinly bedded and to stand vertically, probably due to an overthrow or eroded anticlinal.

A little further south there is an *anticlinal* and the limestone is a blue variety; in part massive and sub-crystalline in character, and contains thin slaty layers between massive plates; the slaty portion seems to contain a great deal of *hydro-mica.*

Following the road, after it leaves the Bushkill, in its western branch, close to Seips', a dove-colored, very siliceous limestone is met with; which may possibly be a part of the Calciferous sand-rock, but does not look like it. Returning to the eastern branch of the road over Chestnut Hill

a dark blue, semi-crystalline variety is met with near the top of the hill, having a north-west dip.

From the point where the Bushkill turns eastward, deflected by the Laurentian rocks of Chestnut hill, to its mouth, the limestone is everywhere blue to dove-colored, semi-crytalline to compact and occasionally containing thin layers of *damourite.*

Following the road from Chestnut hill to Churchville, a north-west dip is seen on a line with mine No. 20, and several thousand feet west of the road. The limestone at this point is bluish-gray, saccharroidal and somewhat *oölitic.* Continuing northward to where there are three south-east dips, east of the road, the limestone is found to be dark blackish-blue, semi-crystalline and full of spots of white calcite, once probably *fossils* and now obliterated. Taking the north south road east of the one just followed, there is a limestone full of *pyrites*, having a south-east dip, just opposite C. Sandt's house. The same is true of the outcrop opposite A. Price's house, the rock being light grey and partly semi-crystalline.

Near J. Miller's the magnesian limestone has a saccharroidal character; and just below William Schug's it is *oölitic.* Everywhere else between Martin's creek and Chestnut hill the magnesian limestone presents its normal appearance.

Along the Bath railroad the limestone presents a tolerably uniform character. It is usually blue to grey to dove-colored, while the rock varies from compact to semi-crystalline, occasionally a somewhat *brecciated* or an *oölitic* bed is met with. An instance of the brecciated structure is met with at P. Lerch's quarry, close to the railroad on the Bethlehem-Nazareth road.

At the quarry having a south-east dip, about half a mile east of mine No. 16, the lower beds are thickly bedded, while the upper ones are in thinner plates, probably owing to weathering.

At the outcrops between mines Nos. 15 and 16, the limestone is blue and shaly, being somewhat curved and twisted at one point. It is well to note the change in the direction of dip at this point compared to the quarries on the same

road nearer Newburg, where the dip is south-west. There is no change in the surface topography to account for this change of direction, the cause of which is unknown.

At the quarries last mentioned, the limestone is very shaly and of an earthy character, being of a greyish-blue color.

The limestone at the dips just east of Hecktown is *brecciated* and there is an anticlinal roll in the quarry.

On the road between Newburg and Nazareth, at the arrow dipping south-west 14° on W. Hellick's farm, there is an anticlinal which is seen to continue to the north.

To the north on the road leading from Nazareth to the poor-house slaty limestone crops out, having a south-east dip, and the same limestone appears with a reversed dip on a short oblique road.

Wherever rock crops out on the road between Christian spring and Bath, it is seen to be a shaly limestone, until just before entering Bath, where it is slate.

Passing from Christian spring to Georgetown there are some quarries to the west of the road in which the limestone is dark blue, semi-crystalline and unevenly striated.

On the road from Georgetown to New Centreville the limestone is full of thin layers of *damourite*, about the thickness of a sheet of paper.

Between New Centreville and Smoketown the limestone is saccharroidal and somewhat *brecciated*. There are cavities full of calcite, which once contained *fossils*, now obliterated.

About half a mile east of mine No. 6, and south of the Bath railroad, there is a limestone quarry on D. Gradwohl's farm, dipping south-west 48°. It is grey, massive and contains small crystals of black calcite; also, rounded masses of white calcite, which were evidently once *fossils*, but are now obliterated.

A little north of Hanover there is a monoclinal of limestone, in which the rock is in rather thin sheets, while a short distance to the west it is massive.

West of New Centreville the limestone is massive and in places contains a good deal of *chert*.

Returning to the Hanover Bath road, this crosses a short

steep limestone hill, having a northern dip, which is extensively quarried. The rock is dark blue, semi-crystalline and in thick beds; it was apparently once *fossiliferous*, but the cavities have been filled with white calcite and quartz.

In the borough of Bath the limestone near the railroad is very shaly, and in places resembles slate. It is of an earthy and compact nature.

A little south of the town and west of the railroad, hydraulic limestone appears.

Near the short south-west road leading from Bath to the Siegfried's Bridge—Nazareth road, there are three north-west dips of 18°, 10°, and 20°. The limestone at this point is grey to blue, massive to shaly and semi-crystalline; in the quarry at this point specimens of *Maclurea* or *Euomphalus* have been found. A little further south at the quarry dipping 17° north-west, specimens of gasteropods and helicæ occur rather abundantly. These tend to show that the limestone at these localities is of *Calciferous age.*

Still further south there are a large number of dips having a general north and west direction; the rock is semi crystalline, and there are cavities through it evidently once containing organic remains, but now partially filled with calcite.

From this point west to the Lehigh river all the limestone outcrops along the main east-west road show that the rock is of the *hydraulic* variety.

In East Allen township at H. Danner's, north of this road, the limestone is dark blue, and in places almost black; it is semi-crystalline and possibly extends to the top of the hill. As the surface of the ground is covered to the depth of a foot with small pieces of slate, which may or may not be in place; it is impossible to fix accurately the boundary between the two formations.

A short distance north of the last locality limestone again crops out at S. Jacoby's, being dark blue and crystalline, and overlaid by Hudson River slates, (No. III), much broken up.

About half a mile east of the locality just mentioned, the

presence of limestone is indicated by bowls or depressions, so characteristic of this rock, but there is no outcrop.

A third of a mile north of this limestone is quarried by John Laubach; it is dark blue and semi-crystalline. The limestone forms a small synclinal, and there are obscure traces of bivalve *shells* and small fragments of *graphite.* Overlying the limestone and filling the synclinal to the surface, a distance of about fifteen feet, are the Hudson River slates (No. III).

Limestone again shows itself about a quarter of a mile west of Seemsville, near the road to Kreidersville; it is dark blue and semi-crystalline. Over this are the Hudson River slates in place, but much broken up and *conformable* with the former rock; they have a thickness of four to eight feet and reach to within two feet of the surface, being then replaced by clay.

A short distance to the west there is another outcrop of limestone, which is dark blue, and some of the beds are brecciated, while others are *oölitic.*

East and west of Weaversville the limestone seems for a considerable distance to be shaly. About one and a quarter miles east of the village there is a small hill, where the limestone has been much folded; the rock itself is colored blue and white in stripes.

About a mile north of Catasauqua, where the limestone dips south-east 36°, it is dark blue, massive, thickly bedded and much contorted.

Along Catasauqua creek, north-east of the town, the limestone at times contains thin beds of *damourite* slates; again it is brecciated or *oölitic,* while in places it is massive and compact.

In the eastern part of the town are the two quarries belonging to Ran and Jesse W. Weaver, figured in Report DD, which so clearly proves the correctness of Henry D. Rogers' theory as to the prevalent south-east dip of the limestones already mentioned.

Between Weaversville and Shœnersville is a limestone hill in which this rock occurs in thick beds of a compact variety, alternating with thin shaly ones; there are also

thin sheets of *damourite* slate running through the rock. In a quarry east of the road there is a beautiful roll in the limestone.

About one and a half miles south-east of Catasauqua there are three south-west dips on the road leading to Bethlehem; the limestone is pale blue to white, thinly bedded and of a saccharoidal nature.

A quarter of a mile east of these, on the road leading north to Shœnersville there is a bed of limestone between solid strata of the same rock, which is decomposing to a clay.

Returning to the Catasauqua-Bethlehem road, limestone is seen dipping 42° to the north-west, a little north of the road; being *brecciated* in character.

A little further south-east on the same road the limestone outcrops are of the normal kind; and the same is true of all the other outcrops between this point and Bethlehem.

Just north of East Allentown a portion of the limestone is *brecciated* in some places, and in others of a sandy nature.

On the north-south road west of Rittersville all the outcrops are those of the normal limestone.

The limestone outcrops between the Lehigh river and the Laurentian hill, north of this stream, are of the normal variety.

4. Analyses of the Magnesian limestones.

The probable origin of the dolomites and dolomitic limestones has been a favorite theme with many geologists and chemists; and as a natural result many theories have been offered as to their probable mode of origin.

In many cases however wide generalizations have been attempted from very limited occurrences of such rocks or from mere laboratory experiments, which were based either on insufficient evidence or else on a forgetfulness of the fact that nature often operates in a manner far different from the chemical laboratory since she has one important element, viz: time, to aid her in her operations, which the chemist lacks.

The magnesian limestones of the Great Valley vary from compact to semi-crystalline; are of various colors; contain

very few fossils and these concentrated in a very few localities. The beds nearest the surface are those which have been the most honey-combed by the dissolving action of water; when deeper beds are exposed in quarries they give little evidence of such action.

Analyses of these rocks show that they *all* contain slight traces of carbonate of magnesia, which some of the beds contain a quantity almost sufficient to constitute them true dolomites.

The percentage of magnesia varies however inside of each bed, and this suggests that the sediment was not a chemical double carbonate of lime and magnesia, with excess of carbonate of lime, but that it was *a mechanical mixture* of a carbonate of lime with a carbonate of magnesia.

Analyses of specimens from 115 conformable beds exposed opposite Harrisburg, made by Messrs Hartshorne and Hartranfft in the laboratory of the survey,* show: 1. the alternation of magnesian and non-magnesian beds; and 2. the variable percentage of magnesia in each bed.

A specimen group will suffice to exhibit this. The following are analyses of the first ten beds at one end of the exposure:

Bed.	Lime Carb.		Magnesia Carb.		Insol. Matter.	
	Grade.	Top.	Grade.	Top.	Grade.	Top.
1	58.35	57.10	36.80	38.25	4.60	4.00
2	55.60	56 20	38.50	39.75	5.30	3.80
3	89.90	92.00	3.60	4.00	5.70	4.10
4	93.90	97.05	1.80	1.85	3.80	1.40
5	96.40	97.20	1.40	0.70	1.90	2.10
6	95.50	97.60	1.40	1.30	1.50	1.10
7	87.10	87.40	3.60	3.70	9.70	9.10
8	82.30	87 45	14.50	7.50	3.10	3.90
9	68.30	67.60	24.80	27.00	5.50	5.40
10	90 70	90.40	8.05	8.15	1.90	1.70

A series of analyses by J. B. Britton of nine beds at Troxall's quarry, Lehigh county, published in Report D[2], 1878, page 16, show the same variability and disposition to alternation is groups thus:

	Lime Carb.	Mag. Carb.
Bed A, ...	85.20	5.89
B, ...	76.79	17.03
C, ...	78.23	14.54

* Published in Report MM. 1879, page 312.

D,	61.53	26.84
E,	70.10	20.08
F,	65.91	3.14
G,	71.98	8.34
H,	58.30	2.29
I,	89.46	0.63

When beds A, B, C, D and E, were sub-divided into 13 and analyzed by W. Jas. Gayley, the following was the result:

		Lime Carb.	Mag. Carb.
Bed A,	Layer 1,	77.12	0.89
	2,	80.35	1.06
	3,	81.92	1.64
	4,	81.59	7.32
	5,	79.45	3.84
Bed B,	1,	76.02	1.31
	2,	86.26	0.40
	3,	83.87	4.03
	4,	72.07	3.28
	5,	76.92	2.43
	6,	73.95	3.00
Bed C,	1,	66.45	15.26
	2,	54.11	14 11
Bed D,	1,	75.76	4.26
	2,	60.87	1.76
	3,	84.25	2.34
	4,	50.07	1.28
Bed E,		87.43	0.46

Analyses of specimens from a series of beds in F. Eberhard's quarry, in Lehigh county,—beds geologically lower in the formation than those at Troxall's quarry—were made by Mr. Jas. Gayley, with the following result, A being the top and N the bottom bed of the exposure:—

	Lime Carb.	Mag. Carb.
Bed A,	55.39	35.05
B,	54.39	36.26
C,	68.10	21.07
D,	60.86	26.54
E,	63.77	23.43
F,	59.72	21.00
G,	54.67	27.10
H,	64.15	23.17
I,	59.69	32.69
J,	57.16	25.99
K,	59.59	31.03
L,	58.87	25.49
M,	50.25	21.64
N,	57.41	9.38

The *silica* varies thus:—2.20, 3.05, 2.99, 3.75, 3.54, 4.36, 11.58, 5.78, 5.59, 7.34, 2.86, 5.96, 4.21, 15.86.

The *ferric oxide* and *alumina* (together) vary thus:—6.68, 6.57, 7.45, 8.22, 8.53, 14.42, 6.41, 6.53, 1.66, 9.04, 5.91, 9.16, 14.31, 16.85.*

The *phosphorus* varies thus:—.007, .019, .026, .017, .015, .007, .013, .005, .011, .003, .002, .012, a trace, .017.

A residue of *carbonaceous matter*, varying from 0.12 to 0.84, was left when any of the limestones were dissolved in acids. This represents the organic life of the waters.

All analyses of Siluro-cambrian limestones show the presence of this carbonaceous element in the rock. Those made at Harrisburg give .166, .178, .200, .220, .250, .266, .288, .300, .450 (in bed 29,) .540 (bed 25,) up to .560 (bed 53.) Life must have been very abundant in the water, when its remains could make up more than half of one per cent. of a layer of mud at the bottom.

Bischoff was unable to decompose carbonate of lime by carbonate of magnesia, and, therefore, opposed the theory of the chemical precipitation of the latter in the form of magnesian limestone.†

Sheerer professes to have accomplished the reaction, but does not give his process. His artificial dolomite may have been a mechanical mixture.‡

The chemical theory, however, is sustained in some measure by natural pseudomorphs of dolomite after calcite, often with a nucleus of unchanged calcite, or with a vacancy left by the total solution of the calcite.§ As most of these pseudomorphs occur in mineral veins, the agent must have been (probably hot) magnesian waters; and the carb. mag. must have decomposed the carb. lime. Heat and time are factors in such a process.

But the chemical infiltration theory of the formation of

[*Adding 15.86 to 16.85 we get 32.71, or *one third* of the bed in the condition of sand and mud. It is no wonder then that occasional beds and groups of beds of calcareous sandstone, or even of nearly normal sandstone, were deposited widely in the waters of the Siluro-Cambrian sea.—J. P. L.]

† Lehrbuch, 2d edition, III, p. 89.

‡ Beiträge zur Erklärung der Dolomitbildung, p. 13.

§ Blum. Die pseudomorphosen der Mineralreichs, p. 52; and 1st supplement, page 22.

our magnesian limestones must encounter a great objection in the unequal distribution of the magnesian carbonate through the mass. It should be either equally or progressively distributed. On the contrary, specimens from the same bed vary greatly, and beds in actual juxtaposition still more. For instance, *bed 19* has 30.8 p. c. C. M., and *bed 20* has only 2.9 p. c. Thin beds of dolomite lie *between* thick beds of limestone, and thin beds of limestone *between* thick beds of dolomite. The analogy between this and shale bands in masses of sandstone, or sand partings in shale, makes it hard to believe that the limestone and dolomite beds are not mechanical or mud deposits of mixed materials, floated from a distance by currents from different sources, and prevailing over each other alternately.

Forchhammer imagined that the limestone water of rivers flowing into a sea holding magnesian salts would produce dolomite beds, but when he tried the process with boiling water he could only get 12.5 per cent. of magnesian carbonate in the precipitate.

Sterry Hunt modified the theory by supposing the river water charged with carbonate of soda, but the fact of alternate magnesian and non-magnesian beds is still in the way.

Dr. Hunt imagined solutions of sodium carbonate, poured by rivers into a *shallow closed sea*, holding in solution sulphate or chloride of magnesium, and then, by the action of heat, in the presence of carbonate of lime, the deposits changed into dolomites; but the whole mass would necessarily be homogeneous; alternate beds would not be possible, without a corresponding number of entrances of the waters of an outside ocean.

Hardman makes this very objection to Hunt's theory that nearly pure limestone beds lie between highly magnesian beds, and shows that a separate precipitation of carbonate of lime would not begin until at least three fourths of the sea water had been evaporated, the carb. mag. still remaining in solution, and for a considerable time longer; in fact, not until concentration had proceeded so far as to make animal life impossible.*

* On the carboniferous dolomites of Iceland, Proc. R. I. A., (second section,) Vol. I, No. 7.

[The main force of these objections, however, is derived from the vast extent of the deposits, for they spread, continuous at the surface or underground, from Canada to the Gulf of Mexico, and from the Blue Ridge to beyond the Mississippi river. A sea of such extent could hardly have been closed, and must have received great rivers. But during the long Siluro-Cambrian age great erosion of land surfaces must have taken place, furnishing mechanical sediments; or if the ocean were merely studded with islands, coral reefs would furnish such sediments.—J. P. L.]

5. *The Iron ore mines in the limestone.*

The great majority of the ores which occur in the limestones of the Great Valley are *limonite*, more commonly known under the name of *brown hematite.* It is the hydrated ferric oxide, having the formula $2 Fe_2 O_3, 3 H_2 O$, and containing when pure 59.89 p. c. of iron. In practice, however, the greater portion of this ore when hauled to the furnace will not hold more than 35 to 40 p. c. of iron, due in part to the impurities (chiefly silica) intimately combined with the ore and which cannot be removed by any process of washing; in part, however, to the imperfect washing, which leaves flint and damourite slate intermingled with it. In Williams township, the variety of iron ore known as *lepidocrocite* is found associated with the brown hematite, which when pure has the formula $Fe_2 O_3, H_2 O$, and contains 89.9 p. c. of the peroxide. This latter is only a mineralogical curiosity, as it does not occur in any quantity.

As stated in a previous report, the brown hematite occurs massive, earthy, botryoidal, mammillary, concretionary and sometimes stalactitic. Its luster is generally dull and earthy, sometimes silky to sub-metallic. The color of the surface of fracture is various shades of brown, commonly dark; when earthy, brownish-yellow to ochre-yellow. The streak is yellowish brown. When stalactitic it forms the *pipe-ore* which is rather scarce. When concretionary it forms hollow spherical masses, commonly known as *pot* or *bombshell ore.* These hollow masses commonly contain water or masses of unctious damourite clay; their interior surface

often presents a glazed appearance, due to a very thin coating or incrustation of oxide of manganese, which imparts a nearly black varnish-like surface. Sometimes the bombshell ore is solid; its interior then presents a honey-combed appearance, as if from the percolation of chalybeate waters into the mass after the exterior shell has been formed; although this is probably not the case. The great mass of the brown hematite iron ore occurs in small pieces which have to be separated from the enclosing gange by washing.

When the brown hematite is *in place* it almost invariably occurs in damourite slates or in the clays resulting from the decomposition of these last.

Mines along the Foot of the South Mountain.

All the mines along the base of the South Mountain from the Delaware river to Mary Brotzman's mine, No. 47, are underground workings, the stripping necessary to open workings being in most cases so very heavy as to preclude the ore being extracted to profit in that manner.

Owing to the plastic and yielding nature of the clay in which the ore occurs, the gangways driven in search of ore through the clay or on the ore itself have to be most carefully timbered at a considerable expense, which is greatly increased by the fact that if the gangway is abandoned the timber is left behind. The method of mining does not seem to be based on any scientific or regular method, but as a rule the gangways are driven wherever the ore is supposed to exist. Owing to this irregular and in fact deplorable method of mining, as new ore is found from time to time, it often happens that old workings are re-worked at an expense much greater than that at which the ore could have been originally extracted. For the slipping of the clay, as the timber rots and is crushed by the superincumbent weight of materials, renders it necessary to drive new headings through a mass of—so to speak—moving clay, thus occasioning a greatly increased amount of dead-work, besides which heavier timber has to be used. It sometimes happens that in this way old workings are gone over two or three times at an interval of several years. Until the past

year not a single mine was ever surveyed under ground, the first work of the kind having been done by the Glendon Iron Company during 1878, consequently the mining has been for the most part of a happy-go-lucky sort, by which the ore was met or missed as the mine-boss was more or less acquainted with the character of the ore deposit. It is greatly to be desired that the Legislature should pass a law, as in the case of the coal mines, compelling the owners of all underground workings to have a map of the excavated ground ; a measure which is the more necessary as in case of abandonment and subsequent renewal of the work, inundations and possible loss of life would be averted. Such maps would cost the owners but little and would be of incalculable benefit in saving much money in searches for ore which had long since been removed and the fact forgotten.

By the method of timbering adopted, and which is rendered absolutely necessary by the nature of the country, the top and sides of the gangways are completely incased, so that nothing of the nature of the ore-deposits can be seen except at the headings. Most of the mines were visited, several of them more than once, in hopes that it would be possible to ascertain the nature and approximate size of the beds of ore. This was found to be impossible, and hence no data of any value can be given as to the appearance or character of the ore-deposits. The mines have been worked in some cases for 35 years, and some of them are very deep, as in the case of a mine belonging to the Glendon Iron Co., which is — feet below the Lehigh river.

The following is the list of mines thus worked underground :

George Seibert's mine, No. 28.

James Hess' mine, No. 29.

Mrs. Lewer's mine, No. 30.

George Seibert's mine, No. 31.

Glendon Iron Co.'s mine, No. 32.

John Woodring's mine, No. 33.

Miss Miller's mine, No. 34.

Joseph Sampson's mine, No. 35.

Sampson & Sitgreaves' mine, No. 36.—Kenneth Robertson, Esq., Assistant Sup't of the Bethlehem Iron Co., analysed the ore from this mine in 1874 and found:

	I.	II.
Ferric oxide,	73.14=51.2 p. c. iron,	71.47=50.03 p. c. iron.
Oxide of manganese,	0.44	6.41
Phosphoric acid,	0.58=0.25 p. c. phosphorus.	0.56=0.24 p. c. phosphorus.
Silica,	7.58	3 57
Alumina,	5.82	4.50
Lime,	0.21	0.00
Magnesia,	0.14	0.00
Water,	12.37	13.71
	100.28	100.22

I. is from the upper shaft. II. is bomb-shell ore. These analyses are so rich in iron that it is probable the material analyzed was from picked samples.

Heckman Estate's mine, No. 37.

Adam Hahn's mine, No's. 38 and 39.

Glendon Iron Co's. Mine, No. 40.

Enoch Woodring's mine, No. 41.—This is leased by the Glendon Iron Co., who are reopening it. When visited it had been temporarily abandoned.

William Hahn's mine, No. 42.—This mine is situated in an arm of limestone, which extends up a trough of Laurentian rocks south of Glendon. The mine is not worked, the owners say on account of the large quantity of water; but the general structure of the rocks and soil lead to the opinion that the ore at this point is not present in any large quantity and the beds that are present must be thin.

Daniel Boyer's mine, No. 57.—Leased by Reuben Nolf. This mine had not been worked for some time prior to the fall of 1877, when visited. A few days before work had been recommenced and a shaft sunk to the depth of 45 feet. Thus far but little ore has been found, and it was proposed to sink the shaft still deeper. The ore occurs in an abundance of white clay resulting from the decomposition of damourite slate. Still further to the west were abandoned ore diggings; so far as could be learnt but little ore having been found in the shafts sunk. Close by, Daniel Boyer has

a clay pit which from its brownish color is at times used in the manufacture of paint.

Jacob Crawford's mine, No. 43—is worked by Charles Kichline & Co. In past times ore has been sent from here to the Glendon Iron Co., and the Keystone Furnace. It is said that there are two beds of ore here. A shaft has been sunk 18 feet into the top bed and it was thought the owners would have to go down about 60 feet to strike the main bed below. The top bed is about 6 feet thick and contains plenty of lump ore. There was but little white clay in the shaft with the ore. A little lower down the field, they struck the ore in an abundance of white clay. There was no water in the shaft, nor had any been struck. In a now abandoned shaft 100 feet west of the present one the miners said that limestone had been struck at a depth of 70 feet, but that it was not solid and there was ore underneath it. As this was done several years ago, there may be some error about this on the part of the workmen.

Reuben Nolf's mine, No. —. When visited, a shaft was being sunk and was down 45 feet. So far only a little ore had been struck, which was found in a yellow plastic clay, containing streaks of white.

Thomas Nolf's mine, No.—. A shaft had struck ore at a depth of 37 feet. The ore occurs in a light yellow plastic clay, with streaks of white running through it. This mine was opened in the spring of 1877, after having been abandoned 30 years ago by the Glendon Iron Company.

Mary Brotzman's mine, No. 44, is worked by Kichline. A shaft has been sunk 64 feet to the upper bed, which is said to be 3 to 4 feet thick.

Joseph L. Brotzman's heirs' mine, No. 45, leased by George Unangst, was just being opened when visited. Nothing could be seen except stripping, which was being washed. On the surface at the north side only clay could be seen; in the south end of the opening there was a foot and a half of white clay, containing fragments of ore, but no regular bed.

Mary Brotzman's mine, No. 46.—Leased by Pfeifer & Co. This is an open cut containing alternate beds of dark brown

and light yellow clay, somewhat plastic in character—probably decomposed damourite slate—and containing pieces of ore. There is no regular bed, the material mined being only surface soil and sub-soils. It is very probable that the clay and ore have been washed down from the beds higher up the hill side to their present position. Flint occurs in the clay with the ore. The darker colored clay owes its color to the presence of a little oxide of manganese. The beds have a dip of N. 72° E., 17°, conforming to the slope of the hillside.

Mary Brotzman's mine, No. 47.—Leased by the Glendon Iron Company. At one point of this working there are old drifts which are now being worked by an open cut. In this, flint, ore and clay are all mixed up together, owing to the old underground workings, which having crushed together, caused the entire material to roll together, and thus made it impossible to see anything of the original nature of the deposit. Nearer to the road there are two shafts from which ore is being taken. The ore from this mine was analyzed by

Jacob's mine, No. —. Worked by the Coleraine Iron Company. Here only the surface ore is being taken out, it occurring, associated with flint, in clay. No regular bed could be seen, although one is said to exist beneath the surface of the water.

Richard's mine, No. 49.—Leased by the Glendon Iron Company. This is worked by open cuts 6 to 8 feet deep. But little is being done here, and the sides are so washed as to show nothing of the nature of the ore-deposit. It seems, however, to be stripping and not a true bed.

Mary Brotzman's mine, No. 48.—Leased by Kichline. The ore occurs in damourite slate, somewhat decomposed, but scarcely pays for washing, as there is so little of it. The cut is an open one, only 8 feet deep, 2 feet of which are stripping. At the west end there is ore in the bottom of the cut. Thin streaks of black oxide of *manganese* occur in the face of the working, prettily crystallized. When the mine was visited, the workmen were carefully washing and picking this out as being injurious to the ore, and ere much

surprised at being told that by leaving it in they improved the character of the ore.

Thomas Richard's mine, No. 50.—In the open cut this is only worked in the east end, where there is a good body of ore, which seems to be cut off further east by white clay. The ore occurs apparently instratified in the white clay. To the west a shaft has been sunk down 107 feet to the ore. In going down a body of damourite slate and clay was struck, which at a greater depth turns into a blue clay. Underneath the ore there is said to be black dirt, but none could be seen. The bed is said to be 27 to 40 feet thick, but this had to be taken on hearsay evidence, as the mine was so closely timbered that it could not be measured. East of this another opening has been made in the roadside, but so recently that only stripping was being taken out and washed.

Samuel Lerch's mine, No 59.—This was formerly leased by the Coleraine Iron Co., who took out about 50 tons of ore and then abandoned it. The excavation is now almost filled up, and is overgrown with underbrush. The ore was taken out of drift and surface soil. There seems to be a good deal of ore in the surface of the field; but it is very questionable whether it would pay to wash the surface soil for it.

Mines in the South Mountains.

The brown hematite mines in this list occur in the detached limestone basins within the area of Laurentian rocks.

Charles Walters' mine, No 52, is worked by the Durham Iron Co. The ore is extracted by underground workings, the shaft being 60 feet deep down to the ore.

Joy's mine, No. 53.—These are mined by underground excavations, and were not being worked when visited.

Raub & Lerch's mine, No. 54.—But little ore was being mined when this pit was visited, owing to a scarcity of water. Shafts have been sunk through the overlying soil and clay to the ore, which apparently lies irregularly, as in some cases it comes within 15 feet of the surface, while in others it is only struck at a depth of 100 feet. The miners

stated there are three beds, the one worked occurring between two lean ones, which it does not pay to extract. The ore occurs in white or grey clay, resulting from the decomposition of damourite slate.

Joy's mine, No. 55.—Here there are two shafts which were not being worked when visited. The bed was said to be 50 to 75 feet below the surface. The ore occurs in damourite slate and clay, and a number of pieces of the slate laid on the dump.

Stout & Riegel's mine, No. 56.—This locality was worked for a short time by the Coleraine Iron Co. and then given up. Nothing of the nature of the ore-deposit could be seen, but the proprietors said there was a great deal of ore present.

The peculiarity of this locality is that *magnetic* iron ore occurs within a short distance of the brown hematite.

All the brown hematite mines thus far mentioned occur at the base of the Magnesian limestone, (No. II), and close to its contact with the underlying Potsdam sandstone or Laurentian rocks.

Those to be hereafter described, lie higher in the limestone measures, either sporadically and not *in place*, or else close to the contact of the limestone with the overlying Utica or Hudson river slates.

Mines north of the Lehigh river.

Jonas Biery's mine, No. 1.—This is an old pit, long since abandoned, close to Catasauqua, whose very existence can only just be discerned. The quantity of ore is said to have been small, and from the depth of the excavation consisted apparently only of surface strippings.

Abraham George's mine, No. 2.—Leased by the Saucon Iron Co. This mine is lying idle and is full of water. The sides are too much washed to see anything of the nature of the deposit, further than it occurred associated with a black damourite slate or shale, which is probably *Utica shale*, judging lithologically from the character and position of identically the same shale in Lehigh county near Breinigs-

ville. This shale is full of pyrites, which take fire on exposure, owing to their oxidation, and set fire to the carbon in the slate.

William Chapman's mine, No. 3.—When visited, about 3 to 10 feet of stripping had been removed and there the pit presented a promising appearance. The mine had not been developed sufficiently to say whether there was a large body of ore or not. A shaft had been sunk to the depth of 65 feet which was said to be all the way down in solid ore, but this statement is probably incorrect. The well for water had been sunk down 125 feet. At a depth of 30 feet limestone was struck and going through this, ore was said to be found underneath it(?). The ore is mostly of the bombshell variety, and inside of the hollow bombs white (damourite) clay frequently occurs, but at the depth to which the mine had been excavated no white clay was to be seen; an exception in this respect to the usual occurrence.

Aaron Lerch's mine, No. 4, is leased by the Crane Iron Company. In this mine black clay (decomposed *Utica shale*) is found in which there is a deposit of red ore (so-called "red rock ore"); the clay occurs beneath a small deposit of white clay, over which lies brown hematite in which white and grey clay occur sparingly. The red ore also occurs in the bottom of the mine underneath the black clay. The sides of the mine were very much washed and it was difficult to see much of the nature of the deposit. Joseph Hunt, Esq., Ass't Sup't of the Crane Iron Co., furnished me with the following partial analysis by Mr. James Gayly, Chemist of the Co.:

Silica,	25.62
Alumina,	2.12
Lime,	2.08
Magnesia,	0.96
Manganous oxide,	1.26
Metallic iron,	41.48
Phosphorus,	0.483

William Shimer's mine, No. 5, is an old pit long since abandoned.

Simon Ritter's mine, No. 6.—This is not being worked at present. On the south side of the mine occurs limestone,

much waterworn. Dipping S. 38° E., 34°, this being the only certain dip, although there are several points in the bottom of the mine where the limestone appears. Close to this dip there is a little white clay, but not in any abundance. It is possible that the ore has here been washed into a depression of the limestone and was not originally deposited there; in which case ore need only be looked for in the sides and not at any great depth. One very important fact militates against this view, and that is that in an abandoned mine on the opposite side of the road, now filled up, there occurs black clay (*Utica shale*) containing great lumps of iron pyrites, which turn on exposure to sulphate of iron and effloresce. This would tend very strongly to prove that the ore of both the mines is *in place*, and the limestone is the underlying *Trenton* limestone (No. II.) in which no further search for ore need be made. There also occur large flints associated with the iron ore.

Henry Goetz's mine, No. 7.—Leased by the Coleraine Iron Co. This is one of the oldest mines in the county and was finally abandoned in 1877 as being worked out. When visited in 1875–76 the bottom was full of water and ore was being taken out near the top at the northern end, where a little red ore was left. As seen close to the bottom the ore occurs in and above a black clay (*Utica shale*) which containing a good deal of pyrites—perhaps marcasite—oxidises rapidly on exposure and the surface is covered with an efflorescence of sulphate of iron. A little reddish sandstone was seen on the dump, but could not be found on the sides of the mines, although carefully searched after. Over the black clay there occurred in spots heavy bodies of white clay, in some places containing ore, in others none whatever, It is probable that the *Utica shale* seen here is a remnant of the period when the whole of the limestone was covered by the slates (No. III) and that being caught in a *synclinal* of limestone it was preserved from erosion at the time when the great body of slates was washed away. Many thousands of tons of ore have been taken from this excavation and it is a curious coincidence that the mine should have been exhausted just about the time that its aged owner died.

Gernert's mine, No. 8.—This has not been worked for some time and its sides are much washed. At one point in the mine there is a dark liver-brown clay (*Utica shale*) containing glistening particles of pyrites. On the dump there is a little white clay.

Merwin & Schortz's mine, No 9.—Here nothing could be seen, except a little yellow clay; the mine not being worked at present.

Milton H. Kohler's mine, No. 10.—On the north side of this excavation there is a heavy deposit of white clay coming to the surface; the pit being chiefly worked at the west end, where there is a good show of ore, a good deal of which is of the bomshell variety; this occurs imbedded in seams of white clay. Close to it there are limestone bowlders, formed by the dissolution of limestone, containing thin beds of hydromica slate. The white clay seems in part at least to have been formed by the solution of limestone containing damourite.

William Ritter's mine, No. 11.—This is not being worked and the machinery has been removed. This deposit is apparently confined to the surface and is not in place. It looks as if the ore had been washed in during the Drift period, and it is associated with pieces of flint and bowlders of limestone. The sides are much washed.

Samuel Schortz's mine, No. 12.—But little work has been done here, as only a small hole about 10 feet deep has been dug, and the stripping from this drawn to make a road for a washer.

Solomon Hummel's mine, No. 13.—At this place only the stack for the washer has been erected and 5 or 6 shafts sunk within a diameter of 50 feet. There is a great deal of large lump ore at the mouth of each shaft, so that the locality presents a promising appearance.

Samuel Schortz's mine, No. 14.—This has not been worked for some time, so that as usual in such cases, the sides are much washed. In the most eastern part of the pit there is a little white clay on the north side, containing fragments of damourite slate, but this is too little exposed to justify any conclusions. In the most northern part of

the mine white clay again appears, which is apparently stratified; and below this, yellow clay containing angular flints, which also apparently occur in the white clay; but the white clay here contains a good deal of yellow clay—also plastic—disseminated through it, so that when moistened the whole presents a yellow appearance. As this part of the pit is inaccessible it could not be viewed very closely. At the east and north end there is an abundance of ore distributed through the yellow clay.

The whole appearance of the mine is that of a secondary deposit and seems to point to the ore not being in place. All through the yellow clay there are fragments of rock—limestone, damourite slate, and quartzite. The two former are angular, the latter more rounded. The conclusion arrived at by the writer is that the entire deposit has been formed during the Drift period; the ore, rock and clay having been pushed down from deposits to the north or north-west and deposited here in a depression of the limestone rock. The western portion of the mine is considered to be exhausted, and mud from the washer has been run into it.

William G. Becks mine, No. 15.—This has not been worked since 1873. The west end is inaccessible on account of water. The ore *apparently* occurs stratified in white clay, with white clay over it. At this mine the white clay comes within six inches of the surface and is about 15 to 18 feet thick, and there are alternate layers of ore and clay about 12 feet thick. From the small exposure it was impossible to arrive at any conclusion as to whether the ore was *in place* or was a secondary deposit.

J. Beck's mine, No. 16.—Leased by F. Jobst. This has not been worked since 1873. But little could be seen on this account, but the whole deposit looked as if it was a secondary one and not *in place.* A good deal of ore has been taken out, however, which is not often the case with deposits of a secondary character.

John Lawall's mine, No 17.—Leased by the Crane Iron Co. This has not been worked since 1874. In the middle of the north side a single spot of white clay is visible. In

places small fragments of slaty limestone containing damourite and small bowlders can be seen. It looks like a secondary deposit. The ore was found to be so unsatisfactory that work was stopped at the mine in the Fall of 1878. Joseph Hunt, Esq., Ass't Sup't of the Crane Iron Co., furnished me with the following partial analysis made by Mr. James Galy, the company's chemist:

Silica,	24.62
Lime,	1.74
Manganous oxide,	2.92
Metallic iron,	42.84
Phosphorus,	0.431

Jacob Wooding's mine, No. 18, is abandoned and grass-grown. There is a very little wash-ore in sight, and a very small quantity of ore to be seen at the mouths of the trial pits sunk around the excavation.

Gernert and Hellers mine, No. 19, has not been worked since 1874. On the washed sides are small pieces of fresh and partly decomposed damourite slate and ore. The former is of a grey color. There are numerous pieces of quartzite both round and angular from the size of a large watermelon to very small pieces. The ore on the dump is much of it very light, and the large lumps in some cases contain brecciated damourite slate, as if this had been cemented together by the hydrated ferric oxide.

Messinger & Woodring's farm, No. 20.—Here several shafts have been sunk, which are now closed. The ore at the mouths of these is abundant and the appearance is promising.

Benjamin Moser's farm, No. 21.—At this point pipe ore was formerly taken out, and sent to the Glendon Iron Company, but it has been exhausted for 30 years and is filled up.

Enoch Fogel's mine, No. 22.—Leased by the Allentown Iron Company. No excavation has been made on the property, as the panic of 1873 came on just after the lease had been made and the machinery erected.

M. Young's mine, No. 23.—This has scarcely been developed, beyond sinking a well and commencing to erect machinery.

Samuel C. Shimer's mine, No. 24.—Has not been worked for a long time, and there is nothing to be seen.

Dr. B. C. Walter's mine, No. 25.—The main excavation has not been worked since 1874, and was much washed. In 1876, when visited, new shafts were being sunk. These had in some cases struck white clay, with limestone below it, but very little ore being met with. The outlook when visited was not very promising.

Thomas Richard, Jr.'s, mine, No 26.—This consists of a tract of several acres, covered with ore pits and surface excavations. The ore apparently only occurs in surface soil, and does not extend to any depth.

Samuel Messinger's mine, No. 27.—This is now abandoned, as but little ore was found. On the dump there are about two tons of pipe ore. In sinking shafts the workmen apparently struck limestone containing a little damourite slate.

Chapter IV.

The Potsdam sandstone.

(By F. Prime, Jr.)

On the map accompanying this report the *Potsdam sandstone* is seen to commence on the northern flank of the South mountains, at East Penn junction, continuing, with a single interruption, all the way to South Bethlehem, and having everywhere a north-west dip. This north-west dip is due to the elevation of the South mountains, of which the sandstone, where it occurs, forms the mere outer skin or shell, but a few feet in thickness, wherever marked by the color on the map.

The Potsdam sandstone, as already described in a previous report, from the point where first seen, close to East Penn junction, to the spot a few hundred feet further east, where it ceases, consists of a hard compact quartzite, of a yellowish color where weathered, and when freshly quarried of a grayish tint. It contains small dots and specks of feldspathic material, which weather out on exposure, giving the rock a more or less pock-marked appearance. The thickness, where it could be measured, was 21 feet, which must be nearly its total thickness, as syenitic rocks occur within ten feet of it, the contact being covered up.

A little distance beyond the quarry the sandstone has been cut away by the Lehigh river for a short distance, but it soon reappears. After the reappearance of the sandstone its *actual contact* with underlying rocks may be seen in an opening close to and on a level with the Lehigh Valley railroad track, which is said to belong to Charles Raw. Here the sandstone is the normal quartzite already described. The dip of the sandstone appears to be *conformable* with

that of the underlying rocks, both being to the north-west, but this conformability may be only local, as the exposure is small and the underlying rocks have apparently a slight roll. The succession of rocks is as follows:

1. Potsdam sandstone.

2. Damourite slate (essentially) containing a little magnetic oxide of iron; only 2 inches thick.

3. A gneissic rock, distinctly bedded, 18 inches thick.

4. A gneissoid rock containing mica and a partially altered hornblende.

5. A hornblendic rock decomposed to a serpentine-like mineral.

6. Syenite.

Rock No. 2 was analyzed by Mr. F. A. Genth, Jr., with the following result:

Silica,	52.09
Ferric oxide,	11.61
Alumina,	19.80
Manganous oxide,	0.07
Ferrous oxide,	2.64
Magnesia,	3.15
Lime,	0.33
Soda,	trace.
Potash,	7.89
Loss on ignition,	3.11
	100.69

It was stated in report DD that the rocks under the sandstone might be Lower Potsdam, but a further examination during the past year has thrown no light on the subject, while their composition would indicate that they are more nearly allied to the Laurentian rocks.

A short distance east of the last locality the Potsdam sandstone has been extensively opened above the railroad by Henry Sellers. The lowest beds of the sandstone have been well exposed and differ much in character from the upper ones. For the upper retain their typical character of hard, compact quartzite, while the lower are a distinct *conglomerate*, or rather a puddingstone, composed of rounded quartz pebbles the size of a man's head to that of a hen's egg or smaller. These lower beds often contain fragments

and rounded masses of red feldspar (orthoclase,) which are perfectly fresh and of a dark red color, imparting a reddish appearance to the entire stratum in which they occur, a portion of the color being due, however, to the peroxidation of the ferrous oxide originally present in the sandstone.

The occurrence of these pebbles indicates that these beds must have been formed close to the shore-line and that the original coast at this point must have been more or less abrupt.

Well-preserved specimens of *Scolithus* occur at this quarry.

East of this point and as far as South Bethlehem the Potsdam sandstone everywhere retains its typical character of a *quartzite.* Wherever it occurs of this character, it makes a most excellent building stone, no better guarantee as to both its appearance and durability being needed than the main building of Lehigh University and those of the Bethlehem Iron Company in South Bethlehem. It is also well adapted to many purposes around blast- and reverberatory furnaces.

At South Bethlehem a change occurs in the nature of the rock, and in place of the quartzite we find a *red shale* occurring in the street close to and west of Dr. Lindermann's residence. At first sight this shale presents an appearance very much like that of the New Red Sandstone, but its location and stratigraphical position show that it must be of Potsdam age. The change in the lithological character of the rock is probably due either to the original shore-line having been very flat and thus given rise, locally to the deposition of silt ; or else, to a stream having poured into the Silurian sea at this point during the Potsdam epoch.

In the rear of Lehigh University the sandstone is seen of the normal type, as well as at other points along this ridge of the South Mountains. It continues to a point a little east of the North Pennsylvania railroad and may be seen in the railroad cut, having a north-west dip and *non-conformable* with the underlying syenitic rocks which dip to the south-east.

The next point where the Potsdam sandstone occurs is

along the hill east of Lower Saucon church. It has not been found directly in place, but its presence is indicated by the number of Potsdam sandstone bowlders; and as the syenitic and gneissic rocks crop out a short distance above the locality colored yellow, that must be its place.

North of the blacksmith's shop near J. Bergstresser's farm, shafts have been sunk in search of brown hematite, which did not find the latter, but which struck Potsdam sandstone much decomposed, as seen by the material on the dumps. Just south of the blacksmith's shop there occur bowlders of the same sandstone along the roadside. They are much decomposed and consist of rounded fine pebbles of quartz and decomposed feldspar.

The last point where Potsdam sandstone was found south of the Lehigh River, is at the east end of Morgan's Hill, close to the Delaware river. Here *conglomerate* occurs, in which the quartz is the size of the first joint of a man's thumb and rounded, together with smaller pieces of feldspar. Above this, geologically, the conglomerate becomes a coarse sandstone, while still higher occurs the Calciferous sandstone, already described.

Passing to the north side of the Lehigh river, the Potsdam sandstone occurs on the syenitic hill between Allentown and Bethlehem. The sandstone, which is of the normal quartzite type, forms a sheet along the north-west border of the syenite, having a general north-west dip, conformable to the upthrow by which the hill was formed. The discrepancy in the dip, as shown on the map, is more apparent than real, being due to the sandstone folding around the flank of the hill, and to local flexures of the rock.

Potsdam sandstone, of the same type, also occurs on the south-east side of the hill, having a general easterly dip, conforming to the contours of the hill. This outcrop is important, when taken with those south of the river, as showing that the latter must have had the change of its course at Allentown in great measure determined originally by a *synclinal* either of sandstone, or more probably of limestone, through which it could find an outlet when its

Topton station, seen from the west.

southerly direction was cut off by the mass of the South mountains.

A single piece of quartzite was found to the north-west of the Laurentian rocks, north of Bethlehem, on the road leading from that place to Shoenersville, but it is uncertain whether the rock was in place, or only a bowlder of Medina sandstone.

The last locality where Potsdam sandstone was seen is south of the blacksmith's shop at S. Seips, east of the road leading to Easton. The arrow dipping S. 12° W., 26° should be moved a little further east so as to be in the gneissic rock. In the spot colored yellow a shaft had been sunk in 1875, in damourite slate, and a little brown hematite iron ore found, but not enough to justify further search. Below the damourite slate Potsdam sandstone was found nearly in place, but much fractured, and below this the gneissic rock, whose dip has just been noted.

Rogers * mentions the occurrence of Potsdam sandstone close to Chestnut hill. He says:

"Both on the south and north sides of the axis [of the hill] the primal (Potsdam) sandstone is very well exposed. On the south side it seems to constitute a separate low arch. It is here largely displayed on the river side, and is very vitreous, much fused and generally of a reddish hue; but a white sandstone of the more normal character is associated with this."

"Just at the north end of the gap there is a considerable mass of Primal (Potsdam) white sandstone, forming a stone-slide or talus. In the north-west flank of the ridge, the sandstone may be seen in place dipping vertically." This ground was gone over repeatedly by several members of the geological corps having this portion of the State in charge, and although diligent search was made for the sandstone mentioned by Rogers no trace of it could be found. Either it has been removed or covered up or by some mistake another rock was taken to be the sandstone.

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* See Rogers' Geology of Pennsylvania, Vol. I, p. 242.

Prof. Rogers * in his final report sub-divides the Potsdam Series (No. I) into:

1. Primal upper slate.—"A greenish-blue an brownish talco-argillaceous slate, sometimes very soft and shaly. Its only fossil a peculiar fucoid."

2. Primal white sandstone.—"A compact, fine-grained white and yellowish vitreous sandstone, containing specks of kaolin."

3. "*Primal older slate*, a sandy slate of a brown and greenish-grey color, containing much feldspathic and talcose matter."

4. Primal conglomerate, which he says does not appear in Pennsylvania and describes as being "a heterogeneous conglomerate composed of quartzose, feldspathic and other pebbles, imbedded in a siliceous or talco-siliceous cement."

Of these formations the result of the present geological survey of Lehigh and Northampton counties has been able to discover the two uppermost divisions of the series.

The *Primal upper slate* is that portion of the damourite slate which forms the transition between the Potsdam sandstone and the Siluro-Cambrian limestone. Rogers states its probable thickness as 700 feet, which it may well be in portions of Lehigh and Northampton counties, while in other places it almost thins out. This damourite slate, which, in the present survey, has been colored as a part of the Siluro-Cambrian limestone area, is the most important of the four divisions named, as it contains the range of brown hematite iron-ores, which lie between the sandstone and limestone along nearly the whole length of the two counties.

The *Primal white sandstone* is the normal Potsdam quartzite of the district under discussion. Its maximum thickness in the counties above named being 30 feet, instead of the probable thickness of 300 feet assigned to it in Pennsylvania. But in Berks county it is much thicker.

The *conglomerate* described in the present chapter probably forms the base of the Potsdam formation in Northampton and Lehigh counties.

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* Geology of Pennsylvania, Vol. I, p. 104.

During the fall of 1879 the writer of this Report had occasion to examine the Potsdam rocks of the Shenandoah or Great valley of Virginia. The observations made then confirmed the views he has long held with regard to the rocks of the Potsdam epoch in the Appalachians, viz: That the bay or coast-line along what is now the western base of the Blue Ridge or South mountains shoaled very rapidly from the south towards the north. The whole structure of the rocks shows very clearly that there must have been a coast bounding the Potsdam sea and lying further east than the present Blue Ridge or South mountains, since this is bordered to the east and west in many places by the Potsdam formation, while at other points we find the latter overriding the highest crests of the mountain-chain, thus proving that this was elevated subsequently to the Potsdam epoch. The facts which tend to prove a greater depth of the Potsdam sea in Alabama, East Tennessee, and Virginia, when compared with Pennsylvania and New Jersey are briefly these:

Prof. Safford,* in his report on the geology of Tennessee, states that the thickness of the Ocoee Formation—which is the equivalent of the Potsdam rocks *below* the *Scolithus linearis* sandstone—may be more than ten thousand feet. The rocks composing the Ocoee formation in Tennessee are said to be mostly pale greenish or bluish, semi talcose (hydromica ?) slates, containing, occasionally, bands of sandstone and conglomerate.

He also says that from Washington county, Tennessee, towards Virginia the Ocoee is by no means so important as the Chilhowee (Potsdam) sandstone. But approaching the Virginia line the group shows itself in considerable masses and forms, in part, the great ridge between Tennessee and North Carolina.

Prof. Safford further states that the Chilhowee (Potsdam) sandstone is a great group of heavy bedded sandstones often dark, but generally weathered to a grayish white and containing great beds of whitish quartzose sandstone or quartzite. At some points sandy shales and thin flags, often containing scales of mica, are interstratified.

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* See Safford's Geology of Tennessee, p. 183, *et seq.*

Some of the sandstones are coarse and approach fine conglomerate. The sandstone often contains *Scolithus* and impressions of fucoids. The maximum thickness is not less than two thousand feet.

Prof. Fontaine * states that at Balcony falls in Virginia the strata underlying the Potsdam sandstone are 417 feet thick, the sandstone itself being 500 feet.

Prof. Campbell † makes the Potsdam formation below the *Scolithus* sandstone at least 1250 feet thick, and the sandstone itself 340 feet.

At Rockfish gap, further north, Prof. Fontaine makes the average of the Primordial rocks to be over 2000 feet, with the coarse materials increasing towards the southwest.

Passing northward to southern Pennsylvania, Rogers ‡ states that the probable thickness of the Potsdam sandstone near the tunnel opposite Jack's mountain, on the old Gettysburg railroad, in Franklin and Adams counties, is probably one thousand feet, but assigns no thickness to the underlying Lower Primal slates.

The explorations of the writer show that to the north, between the Schuylkill and Delaware rivers, the Potsdam sandstones overlie the Laurentian rocks unconformably, and that there are no underlying rocks of any thickness between the two; while in turn the Potsdam sandstone thins rapidly as one travels east, and seems to finally disappear for a time in New Jersey, being but 25 feet thick at Allentown. The facts then briefly stated are these:

1. The Potsdam sandstone, while varying in thickness at different points, thins coming north, decreasing from 2000 feet in east Tennessee to 25 feet in Pennsylvania, and disappearing in New Jersey.

2. There are in the south thick deposits of sandstone and shales underlying the Potsdam sandstone, which gradually thin out, and disappear towards the north.

It would seem, therefore, as if the ocean, inland sea or

*Am. Jour. Sci., III series, Vol. IX, p. 361, *et seq.*

† Am. Jour. Sci., III series, Vol. XVIII, p. 435, *et seq.*

‡ Geology of Pennsylvania, Vol. I, p. 207.

bay, which covered the region now occupied by the Blue Ridge and South mountains must have been quite deep in the south, while it was exceedingly shallow or dry lands in eastern Pennsylvania and New Jersey, as evidenced by the absence of the strata below the Scolithus-bearing sandstone.

The lower Potsdam rocks, if formed along an exposed coast-line like that of Long Island and New Jersey, must in part have been formed, so far as relates to the shales which compose them, at a considerable ocean depth, and some distance from shore, as we know that along a coast, and at a slight depth, only sand would have been deposited, while the finer silt would have been carried out to sea. If, however, these silts were deposited in a long and comparatively sheltered bay or inland sea, protected from oceanic currents, then the shales might have been deposited at depths little below the surface of the water, especially if there were streams pouring their contents into it, as we see the muds now forming in many of the estuaries of our Atlantic coast. There are in places evidence of such streams, as for example at the western end of Rockfish gap tunnel on the Chesapeake and Ohio railroad in Augusta county, Virginia, where for many miles we have red ferruginous shales, containing a set of beds not over 18 feet thick, which contain lean red hemitite, not enough, however, to pay for mining, as they do not average over 30 per cent. of iron. It is scarcely probable that such iron ores could have been deposited in an open ocean, except at very great depths, as shown by the recent Challenger expedition, and there are serious objections to this view.

1st. To have been so deposited the oxide of iron and silicates of alumina composing the shales must have been dissolved out of shells, and the probable paucity of animal life at this period was too great to suppose a sufficient quantity of them to have been present to form the large amount of iron present.

2d. The sandstones interstratified with the shales would forbid the idea of any very great ocean depths, unless each alteration in the composition of the beds was accompanied

by changes of level too stupendous to conceive possible, when we observe the parallelism and conformity of the sandstones and shales. If, however, there existed dry land to the east of the present Blue Ridge from which poured rivers into a shallow inland sea like Hudson's Bay, then no such violent hypotheses become necessary nor even any change of level during the Lower Potsdam period.

There would be currents, both tidal and lacustrine, but the effect of both would be small compared to those of a deep ocean. The rivers pouring into a great bay, having its greatest depth towards the south, would carry in varying materials, both as to character and quantity, according, as the earth was passing through dry or wet cycles. The iron held in solution or more probably mechanical suspension being deposited at greater or less intervals from the river mouths according as the amount of water which they poured forth was greater or less.

At the same time attention must be called once more to the fact that during the formation of the *Lower Potsdam* beds the bay ceased before reaching Eastern Pennsylvania, as no deposits of Lower Potsdam, worthy of the name, have been found there east of the Schuylkill river.

Chapter V.

The South mountain gneiss, &c.

(By C. E. Hall.)

The following notes of an *itinerary survey* of the South mountain ranges, and the included coves and valleys, lying between the Delaware river and the Berks county line, were taken in the autumn of 1882.

The objects of this survey were:—1, to obtain precise data for coloring the *key sheet* in the Atlas; giving a clearer definition to the contact lines where the limestone areas adjoin the gneiss, and to the patches of Potsdam sandstone which remain upon the ancient eroded surface of the gneiss; 2, to furnish the future field geologist with as complete a list as possible of all the *rock-exposures* on and near every road in the district.

These notes can be used to fill in the details of structure upon the sheet maps of the Atlas; and they will be found useful in the future construction of cross sections by those who shall make special studies of localities, especially in the neighborhood of ore mines.

Great care has been taken to define the exact localities of the noted exposures by reference to *churches*, *taverns*, *private houses*, *railway stations*, and *road forks* and crossings. Where none of these were available the course and distance is given from some elevated *summit* marked upon the map by figures, thus: 750′, or 970′. As the notes follow the roads there can be no doubt about the identity of any given summit thus indicated.

The paragraphs are numbered from 1 to 255 so as to facilitate reference by Mr. Hall's special index at the end of his notes.

Mr. Hall's general remarks on the geology of the South mountains in the district surveyed by him will be found at the end of these notes.

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1. Fragments and bowlders of Potsdam sandstone are exposed on Lock Ridge along the road leading from Alburtis to Erdman's limonite mine (No. 54,) south-west of Lock Ridge Furnace.

There are no exposures of the sandstone in place but loose fragments of the rock occur on the northern slope of the ridge and extend to the southern escarpment.

2. Decomposed feldspathic rocks (granulite) are exposed on the southern slope of Lock Ridge west of Lock Ridge Furnace. The rock is much broken and no exposures in place are visible.

The rock is visible along the road leading from Alburtis to Erdman's limonite mine, (No. 54.)

3. Erdman's limonite mine (No. 54) is located a few hundred feet south of Swope creek one mile due south of Alburtis, on the east side of Gardner's station-Alburtis road. The ore lies in lenticular bodies or beds in decomposed hydro-mica slate of a yellow ocher color. About 60 feet of this decomposed material is exposed in the mine.

There is no regularity in the deposit of the limonite. Occasional small bodies of slate are met with which appear to be little affected by the weather.

The whole mass of clay and limonite appears to dip S. 10° E. 15°.

South-west of Erdman's mine for a distance of ½ mile are numerous extensive mines in the same formation. There is no difference whatever in the character of the deposits.

Large quantities of silvery hydro-mica slate are thrown out on the waste dumps. The dip of the deposits appears to be the same in all the workings.

4. Large numbers of loose blocks of gray feldspathic and hornblendic (pyroxene) gneiss or granulite are exposed on are in the vicinity of the Alburtis-Treichlersville road on the north slope of the mountain 980′.

The exposures extend from the vicinity of Hensingersville hotel, $\frac{1}{4}$ mile north of the R. R. to the summit (980′) of the mountain north of St. Peter's church. The rock is usually fine-grained and laminated. The hornblendic (pyroxene) occurs in fine particle,s pink feldspar is prevalent.

There is little mica to be found and the rock is principally quartz and felspar. Throughout the entire northern slope of the mountain there are no exposures of the rock in place.

5. Pötsdam sandstone and quartzite occur at and in the immediate vicinity of St. Peter's church.

One quarter of a mile west of the church near the county line the soil is sandy and occasional fragments of quartzite are visible on the roadside. Just east of the church on the road leading to Shimersville large quantities of quartz and conglomerate sandstone occur in the soil.

The sandstone appears to be confined to a plateau at an elevation of 910′ to 940′.

I was unable to find any trace of limestone in the vicinity of St. Peter's church.

6. Gray granitic gneiss (granulite) is exposed near the St. Peter's church-Shimersville road about 800 feet east of P. Hollman's house, close to a brook which crosses the road.

The exposure appears to be part of a ledge but no dip could be obtained. The rock is principally quartz and feldspar (granulite) with a small amount of mica.

7. Decomposed feldspar and large bowlders of feldspathic gneiss occur along the Millerstown-Treichlersville road and at the crossing of the St. Peter's church-Shimersville road.

8. Light-colored feldspathic quartzose gneiss is exposed on the Millerstown-Treichlersville road on the north slope of the mountain 790 feet a short distance south of Millerstown.

9. A ledge of Potsdam sandstone is exposed in and near the Millerstown-Treichlersville road $\frac{3}{4}$ mile south of Millerstown close to summit 580′. This summit is also formed by Potsdam sandstone.

The rock is a gray fine-grained sandstone and quartzite. The dip is N. 15° W. 15°. The exposures do not indicate a thickness of more than thirty or forty feet. Immediately

south of the sandstone exposures quantities of flint breccia, quartzite and yellow jasper with deposits of drusy quartz occur loose in the soil.

10. Indications of Potsdam sandstone are found at the toll-gate on the Millerstown-Shimersville pike. Quantities of loose sandstone and quartzite occur in the soil, but no exposures are visible.

11. One quarter of a mile south of the toll-gate on the Millerstown-Shimersville pike specular iron ore was mined by Geo. Knaus in 1881.

The mine is located between the toll-gate and W. Foster's house on the west side of the pike.

The ore appears to be interbedded with quartzose felspathic rock and the ore is mixed with quartz. About four feet of ore is exposed. The dip is S. 50° E. 75°.

12. Riegel's red hematite (specular) ore mine is located a few rods south-west of the hotel at Shimersville on the west side of the pike. The ore lies in a bed varying in thickness from two to six feet. The workings are about 120 feet in depth. Decomposed felspathic gneiss (granulite) forms the foot wall of the ore. The hanging wall consists of decomposed chloritic slate.

The felspathic rock is so thoroughly decomposed that it is easily crumbled in the hand. The bed dips S. 70° E. 45° –55°.

13. Shoenley's mine (Crane Iron Co.'s mine) is located a few rods south-west of the toll-gate at Zionsville.

The ore is specular and rests on decomposed felspathic gneiss. Decomposed chloritic slate overlies the ore.

About four feet of ore is exposed in the mine at present.

The rock and ore are easily removed with a pick. The felspathic rock is usually much decomposed and quite soft. The shaft is at a depth of 113 feet. The dip of the ore bed is N. 25° W. 45°.

14. Gackenbach and Kern's mine (Crane Iron Co.) is located a few rods east of the toll-gate at Zionsville.

The ore is the specular or red hematite. The felspathic rock adjoining (underlying) the ore is thoroughly decomposed.

The workings are at a depth of 145 feet. The thickness of the bed varies from five to fifteen feet. The bed dips S. 15° W. 50°–55°.

15. G. Schell's mine is located about $\frac{1}{8}$ mile south-west of Zionsville. The mine is located on the same bed which is developed at Zionsville, (Shoenley's and Gackenbach & Kern's mines.)

The ore as well as the associated rock is the same as found at Zionsville.

16. Bowlders of gray felspathic gneiss (granulite) with particles of magnetite are found along the road west of the toll-house at Zionsville.

17. Between Shimersville and Zionsville the east slope of the mountain 870′ west of the road, is covered with bowlders of gray felspathic gneiss.

18. On Indian creek north of Borger's mill, one mile west of Zionsville quantities of loose fragments of gray felspathic granulite and fine-grained micaceous gneiss cover the mountain (850′) slope.

Particles of magnetite occur in some of the feldspathic rocks.

19. Near the head of Indian creek, north of summit 860′, on the road leading north-west from Borger's mill, a ledge of thinly laminated gray somewhat micaceous gneiss is exposed. Some of the feldspathic gneiss contains magnetite. The dip of the rock appears to be S. 10° E. 80°. The exposure is not extensive.

20. On the cross road west of Borger's hill, which crosses Furnace hill between the summits 860′ and 890′, indications of gray felspathic gneiss are visible on the roadside and mountain slope. Large quantities of loose fragments of gneiss occur in the soil. The rock extends to the southern base of Furnace hill.

The rock is usually a gray feldspathic gneiss (granulite.) Mica is found occasionally in small crystals. Hornblende (pyroxene) also occurs in small quantities.

21. Light colored granitic gneiss and gray gneiss (granulite) with particles of magnetite occur on the south slope of Furnace hill, $\frac{3}{4}$ mile north-east of Hampton Furnace.

22. At the southern base of Furnace hill, east of Hampton Furnace, the soil of the valley has evidently been derived from the decomposition of Potsdam sandstone and slates.

23. West of Hampton Furnace for a distance of $\frac{1}{4}$ mile quantities of quartzite and sandstone occur loose in the soil in the valley.

There are no outcrops of the Potsdam to be found but it is evident that the formation exists in this valley.

24. J. Christman's limestone quarries are located about $\frac{1}{8}$ mile west of Hampton Furnace. The quarries are located close to the Berks-Lehigh county line and just south of the road leading from Hampton Furnace to Perryville.

About 150 feet thickness of rock is exposed in one of the openings, the face of the quarry is about 40 feet high. The rock is drab colored dolomitic limestone.* The dip of the rock is N. 20° W. 80°.

The quarries are opened on the strike of the rock. The dip is somewhat variable. Dip N. 15° W. 78° was also obtained.

25. South-west of Hampton Furnace $\frac{1}{2}$ mile and south of the limestone deposits Potsdam sandstone and quartzite forms a ridge 800′.

26. An extensive exposure of compact gray feldspathic and micaceous gneiss is exposed at the county line on the Zionsville-Treichlersville pike.

The laminations are well defined.

The dip is S. 35° E. 30°. A thickness of about 60 feet of rock is exposed at this point.

27. Large quantities of bowlders of Potsdam quartzite and sandstone occur on the road near the Berks-Lehigh county line a quarter of a mile north-west of Corning station on the Perkiomen branch of the P. & R. R. R.

The bowlders can be traced some distance along the southern flank of the mountain.

28. Gray quartzose feldspathic gneiss (granulite) with grains of magnetite occur along the course of Indian creek west of Bald Hill between the railroad and Zeakel's mill.

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*Analysis by Mr. McCreath of limestone from this locality: Carb. lime, 52.85; carb. mag., 42.77; ox. iron and alumina, 0.65; insoluble, 3.89.

29. Extensive exposures of light gray quartzose feldspathic gneiss (granulite) with some hornblende (pyroxene) alternating with fine-grained black micaceous gneiss occur on the east slope of the mountain on the west side of Indian creek, between Zeakel's mill and Powder valley.

The apparent dip is S. 45° E. ±90°.

30. Just south of Powder valley gray granitic gneiss is exposed in the roadside on the east side of Indian creek. The rock is much broken. The dip appears to be S. 40° W. 70°.

31. Fine-grained gray feldspathic gneiss is exposed on the road ¼ mile west of the Powder Valley store south of summit 870′.

The rock is considerably broken. The dip appears to be N. 60° W. 60°.

32. About half way between Powder valley and the Zionsville-Treichlersville pike dark-colored hornblendic gneiss is exposed just south of summit 760′ near C. Rothenberger's house.

Large bowlders of hornblendic gneiss occur along the road south-west of the Evangelical Lutheran church about one mile south-west of Zionsville.

Dark gray felspathic gneiss is associated with the hornblendic gneiss.

The dip appears to be N. 15° W. 70°.

33. Loose fragments of decomposed dark-colored feldspathic gneiss occur on the road between Zionsville and the Evangelical Lutheran church, one mile south-west of Zionsville.

34. At the Evangelical Lutheran church, one mile south-west of Zionsville, dark-colored micaceous gneiss is exposed in the road. Just south of the church decomposed light-colored feldspathic gneiss (granulite) occurs.

35. Large quantities of loose fragments of gray granitic gneiss (granulite) cover the north slope of Bald Hill south of New Zionsville.

36. On the Hossensack-New Zionsville road numerous exposures of decomposed felspathic gneiss (granulite) with occasional bands of light-colored granitic gneiss occur.

37. On the mountain slope north of Hossensack at an elevation of 500 feet dark-colored slaty micaceous gneiss is exposed in the Hossensack-New Zionsville road. The dip appears to be S. 30° E. 65°.

38. A quarter of a mile north of Hossensack a few rods from the forks of the road Potsdam quartzite and sandstone is exposed on the road-side.

The dip appears to be S. 10°–15° E. ±90°. A thickness of about 150 feet of rock is visible.

The rock forms a terrace on the mountain side.

39. Limestone is quarried a few yards south of the road leading from Hossensack to Hossensack Station (on the P. V. R. R.) ¼ mile north-west of Hossensack.

About 15 feet of rock is exposed in the opening. The dip appears to be S. 30° W. 20°.

40. About ½ mile east of Hossensack, near Fretz's mill, several limestone quarries are opened on a bed of limestone which extends along the south side of Hossensack creek.

The quarry nearest Hossensack belongs to Milton Schantz. The dip is S. 45° E. 40°.

About 15 feet of limestone is exposed. Overlying the limestone from four to ten feet of red soil (New Red, Mesozoic) is exposed.

41. Sol. Schantz's limestone quarry is located south of Hossensack creek near Fretz's mill, about half a mile east of Hossensack.

The limestone has the appearance of being brecciated. Lime shale occurs with the limestone. The rock has the apparent dip W. 55°–60°.

Lime shale in a small quarry adjoining (Wm. Fretz's quarry) has the dip S. 70° W. 60°.

The limestone is separated from the Mesozoic (New Red) sandstone by an escarpment.

42. Quartzite resembling Potsdam sandstone occurs on the road ½ mile east of Hossensack, close to M. Schantz's limestone quarry.

Quartzose feldspathic gneiss occurs in the same excavation, but this rock is broken and its position could not be ascertained.

43. Fragments of Potsdam quartzite occur loose in the soil along the Perkiomen Valley railroad between Hossensack and Corning stations west of Indian creek.

44. Potsdam sandstone forms a well-defined ridge (470′) east of Indian creek a short distance south-west of Hossensack station.

The entire ridge is covered with fragments of gray sandstone and quartzite, but no exposures of the ledge are visible.

45. At the first curve of the P. V R. R. north-east of Hossensack station occurs are extensive exposures of gray feldspathic gneiss (granulite.)

At the south-west end of the cut, the rock is quarried for railroad ballast. The dip is N. 40° E. 70°.

About the middle of the railroad curve the dip of the rock appears to be N. 45° E. 30°.

The rock is a massive granitic gneiss (granulite) with pale pink feldspar alternating with occasional beds of thinly laminated shaly gneiss. The excavation is about one hundred yards long and eighteen feet deep.

About 100 yards north of this point the railroad cuts through broken and decomposed gneiss of similar character. Although the cut is more than one hundred yards long and from ten to twelve feet deep, there was no undisturbed rock observed.

46. Near the northern end of Bald Hill about two thirds of a mile south of New Zionsville are extensive exposures of gray feldspathic gneiss (granulite) on the railroad.

The rock is considerably broken. The cut is about 150 yards long and 18 feet deep. The rock dips N. 30° E. 80° apparently.

47. Near the road which crosses the railroad at the north base of Bald Hill north-east of summit 890′, gray gneiss is exposed. The dip is N. 20° E. 80°.*

48. On the New Zionsville-Fretz's mill road decomposed quartzose feldspathic gneiss is exposed near Hossensack

* There is little or no change in the character of the rock along the eastern slope of Bald Hill. The rock is a gray granulite with pink feldspar and small amounts of mica and grains of magnetite.

creek. The creek defines the southern limit of the gneissic rocks.

49. Dark-colored feldspathic gneiss is exposed on the road leading to Dillingersville from the New Zionsville-Fretz mill road, north-east of summit 580′, about one mile and a quarter north-east of Hossensack.

The dip is N. 20° E. 60°.

50. A few unimportant exposures of decomposed gray feldspathic gneiss occur on the Dillingersville-Shelley's mill road.

51. A few loose bowlders of coarse mottled pyroxene feldspatic rock occur at Shelley's mill. The pyroxene decomposing on the surface gives the rock a porous appearance.

52. Numerous exposures of loose fragments of feldspathic quartzose gneiss (granulite) occur on the Dillingersville-Limeport road, north of Shelley's mill and south of summit 860′. Light pink feldspar and grains of magnetite occur through the rock.

53. Decomposed feldspathic gneiss (granlite) occurs near the blacksmith-shop on the Dillingersville-Limeport road ¾ mile west of Chestnut Hill, ¼ mile north of summit, 800′.

54. Large quantities of loose fragments of gray quartzose feldspathic gneiss (granulite) occur on the road west of summit 880′ of Chestnut Hill. Fragments of similar rock occur on the southern and eastern slopes of Chestnut Hill.

55. Limestone is quarried extensively at Limeport. The quarries are located on the east side of the escarpment of the creek. From sixty to ninety feet of limestone is exposed in the quarries overlaid by twenty to forty feet of slate.

The slate is usually dark colored and has the appearance of a hydro-mica slate. The dip of the limestone varies from N. 45°–80° E.—10°–20°.

The creek at Limeport forms the western boundary of the limestone.

56. Newmeyer's limonite mine is located about ¼ mile east of Limeport.

The limonite occurs in decomposed hydro-mica slate and

Centre mark; Topton station, U.S.C.S.

clay, and from the position of the mine, the slate appears to be equivalent to that overlying the limestone of the quarries at Limeport.

The limonite is deposited in irregular lenticular bodies. The dip appears to be undulating to the eastward 5° to 15°. A large excavation has been made to a depth of about forty feet at the deepest point.

57. Limestone occurs in the low land near A. Brunner's house, three quarters of a mile south by east of Limeport, south of Newmeyer's mine.

58. Gray feldspathic gneiss is found north-east of Chestnut Hill, extending along the north base of the mountain 920′. No exposures of the rock occur.

59. Ferruginous quartz and bowlders of flint breccia occur in the low land (550′–580′) one mile south-west of Limeport, north of Chestnut Hill, in the vicinity of the Chestnut Hill Church—Vera Cruz Station road. The rock is undoubtedly Potsdam sandstone.

60. Gray granitic gneiss (granulite) with pink feldspar and grains of magnetite occurs along the road crossing the ridge 780′ west of Limeport. Loose fragments of the same rock cover the mountain slope.

61. Between Vera Cruz and Vera Cruz station quantities of bowlders of Potsdam quartzite and flint breccia are exposed on the roadside and on the north slope of the mountain 800′.

62. At the north end of the tunnel on the P. V. R. R. ¼ mile south of Vera Cruz, Potsdam quartzite is exposed. About fifty feet of the rock is visible. The dip is S. 30° E. 20° at the tunnel entrance. Near the junction of the quartzite with slaty hornblendic rock, a few yards from the entrance of the tunnel, the dip of the quartzite appears to be S. 30° E. 60°. The northern approach of the tunnel is through decomposed and broken quartzite and sandstone.

63. Slaty hornblendic gneiss occurs in the P. V. R. R. tunnel ¼ mile south of Vera Cruz. The hornblendic rock lies directly against quartzite.

The gneiss has a dip S. 40° E. 80°.

A few feet of the gneiss adjoining the quartzite has the appearance of being affected by a slip or fault.

Dark compact hornblendic gneiss and granitic gneiss with pink feldspar is exposed throughout the tunnel.

The dip varies from S. 40° E. 40° near the north end of the tunnel to S. 40° E. 60° towards its southern end.

64. Bowlders and fragments of gray gneiss (granulite) are exposed on the road west of the P. V. R. R. tunnel near summit 780′.

65. One fourth mile west of Dillinger station on the Dillinger station-New Zionsville road light-colored gray granitic bowlders and decomposed feldspathic gneiss are exposed.

66. A few bowlders of trap occurs on the roadside ¼ mile west of Dillinger station on the P. V. R. R. No dyke is visible.

67. One half mile north-east of New Zionsville north of the tressel bridge of the P. V R. R. an extensive excavation has been made on the side of the railroad in decomposed feldspathic rock. The feldspar is much decomposed and the rock is soft. Occasional bands of dark-colored slaty hornblenic gneiss occur through the mass. The excavation is about 100 yards long and 10 to 15 feet deep.

The dip is S. 15° E. 80°.

68. Fragments of Potsdam quartzite and conglomerate occur loose in the soil at the road crossing the railroad half a mile north-east of New Zionsville.

69. Quantities of loose fragments of Potsdam quartzite cover the ground at the forks of the road ⅝ mile north-east of New Zionsville ¼ mile S. of summit 790′.

70. Large bowlders of gray gneiss (granulite) cover the southern slope of the mountain 850′–930′ ⅝ mile east of Zionsville near and on the Zionsville-Dillingerville road.

71. At the forks of the road north of the toll-gate on the Millerstown-Shimersville pike Potsdam quartzite and conglomerate sandstone occurs loose in the soil on the mountain slope. Feldspar occurs in the sandstone in small fragments.

72. Corundum is found east of the Millerstown–Shimers-

ville pike, one half mile south by east of the toll-house, one fourth mile due east of W. Foster's house, and about one half mile north of Shimersville on the north slope of the mountain.

A number of small openings have been made on the mountain slope.

The corundum is associated with feldspar; but nothing could be seen as to the nature of the deposit. Decomposed feldspar and quartz gneiss (granulite) are exposed near the base of the hill. Some hornblendic gneiss occurs loose in the soil.

The probability is that the corundum occurs in a vein crossing the granulite rocks.

Very fine crystals of corundum occur at this locality.*

73. Gray granitic gneiss, (granulite,) with some black mica and hornblende, (pyroxene,) is exposed along the northern slope of the mountain, 820′ north-east of Shimersville, north of the Shimersville-Emaus road.

74. Brecciated flint and Potsdam sandstone is found loose in the soil just south of summit 820′, one half mile north-east of Shimersville, on the Shimersville-Emaus road.

75. Light colored, thinly laminated quartzose feldspathic gneiss is visible along the north-east slope of the mountain 710′ west of Leipert's gap.

Numerous exposures of decomposed feldspathic gneiss occur on the Shimersville-Emaus road between J. Wetzel's and J. Buskirk's house.

The rock weathers quite white and crumbles readily. It has the appearance of light colored sandstone.

76. Shelley's (old) limonite mine (No. 101) is located just north of Shelly's saw-mill in the northern edge of Leipert's gap. The limonite occurs in decomposed hydro-mica slate and clay.

Shelley's new mines are on the west side of Leipert's gap, opposite the saw-mill at the north edge of the gap. The limonite occurs in decomposed slate and clay. The bedding is irregular and undulating.

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* Dr. E. F. Smith, of Mühlenburg College, Allentown, first called attention to the occurrence of corundum at this locality.

77. At the southern edge of Leipert's gap limonite was formerly mined by the Coleraine Iron Co., (mine No. 100.)

The ore is associated with decomposed slate and clay. Partially decomposed hydro-mica slate occurs throughout the mass. The dip of the measures appears to be N. 45° E. 0°–20° undulating.

78. North of Vera Cruz, ¼ mile on the knoll, 600′ just south of Leipert's gap, large quantities of loose fragments of brecciated flint and Potsdam quartzite occur in the soil. The rock is similar to that found north-east of Shimersville (§ 74.)

79. Gray feldspathic gneiss (granulite) with some hornblende (pyroxene) is found on the south slope of the mountain (730′) west of Vera Cruz.

An exposure of dark gray gneiss occurs on Shimersville-Vera Cruz road near L. Fetterman's house. The rock is much broken and weathered.

80. A small opening (No. 99) has been made for magnetic ore about ½ mile west of Leipert's gap just west of the mountain summit south of the Shimersville-Emaus road near J. Wetzel's house.

Nothing can be seen in the opening. Fragments of the ore on the surface are very silicious. The ore is associated with feldspathic gneiss with hornblende.

81. Thinly laminated quartzose feldspathic gneiss (granulite) with hornblende is exposed in the roadside ¼ mile south of the East Pennsylvania railroad, west of Leipert's gap creek on the Shimersville-Emaus road.

82. Fisher and Donaldson's limonite mine (No. 104) is located at the furnace about ⅜ miles south-west of Emaus.

The limonite is deposited in irregular lenticular beds and pockets in decomposed hydro-mica slate and clay.

The clay is overlaid by six to ten feet of gravel.

83. There are two large limonite mines. Daney's mine (102) and Schwartz's mine (103) between the furnace and the north end of Leipert's gap.

The mines are abandoned and the exposures are poor, but it is clearly seen that the limonite is associated with clay and decomposed hydro-mica slate in both of these openings.

The ore occurs in lenticular bodies and deposits in the clay.

84. South-west of Fisher & Donaldson's furnace, north-east of Leipert's gap south of the P. V. R. R. loose bowlders of gray feldspathic gneiss (granulite) occur low down on the mountain slope and overlie the decomposed slates in many places.

85. Quantities of flint breccia and Potsdam quartzite occur in the soil east of Leipert's gap creek south of the East Pennsylvania railroad and on the Shimersville-Emaus road.

86. Gray slaty hornblendic (pyroxene) and feldspathic gneiss (granulite) are exposed at the western end of Lehigh mountain in the P. V. R. R. cut at the north end of Leipert's gap.

Occasional beds of massive laminated (banded) fine-grained hornblendic gneiss with epidote are found in the cut, some of the feldspathic beds weather rapidly and are shaly where exposed.

The cut is about 100 yards long and 10 to 15 feet deep. The dip is S. 10° W. 35° at the northern end of the cut and varies from 25° to 35°.

87. An extensive cut has been made through clay with fragments of quartzite on the line of the East Pennsylvania R. R. ¼ mile west of Leipert's gap creek.

88. B. Kolb's limonite mine is located a few rods north of the East Pennsylvania R. R. ¼ mile west of Leipert's gap creek. The excavations are only a few feet deep at present.

The ore is associated with yellow clay and decomposed hydro-mica slate.

89. Potsdam sandstone is exposed near the north base of Lehigh mountain just east of Emaus on the Emaus-Coopersburg road near Trexler & Kline's mine.

The dip is N. 70° W. 50°. About 25–30 feet of rock is exposed.

The upper beds exposed in an excavation on the roadside have a porous and uneven appearance and decomposed hydro-mica slate and clay adhere to the surface of the sandstone.

90. Dark gray feldspathic micaceous gneiss bowlders are

visible on the N. W. slope and near the base of Lehigh mountain east of Emaus.

The bowlders extend over the decomposed Upper Primal slates.

91. Gray quartzose feldspathic gneiss (granulite) with grains of magnetite occurs loose in the soil on the north-west slope of Lehigh mountain east of Emaus.

92. Light gray feldspathic gneiss (granulite) is exposed on the southern escarpment of Lehigh mountain near the summit crossed by the Emaus-Coopersburg road, about ¼ mile south of summit 1000 ft. 1½ mile east by north of Emaus.

93. Bitting's limestone quarry is just south of Lehigh mountain, 1½ mile nearly due east of Emaus station, ½ mile north-east of J. Christ's house and ⅛ mile east of J. Bleiter's house, which is on the Vera Cruz-Lanark P. O. road, north of a branch of Saucon creek.

The quarry is at the south-western end of the limestone belt which flanks Lehigh mountain on the south, (Saucon valley.) The limestone is light bluish and drab color. The openings are small. The thickness of rock exposed is about 30 or 40 feet. The dip is N. 65°–70° E. 20°–25°.

94. Schneider's limonite mine, located near the southern base of Lehigh mountain in Saucon Valley, 1¼ miles west by south of Saucon Valley P. O., ¼ mile north-east of F. Egner's house.

The ore is associated with decomposed slate and clay. A number of large openings have been made.

There appears to be no difference in the character of these ore deposits and those on the north-western plank of Lehigh mountain. They undoubtedly belong to the same geological horizon, (Upper Primal slates.)

95. Limestone occurs a few rods south of Schneider's limonite mine, ⅛ mile north-east of F. Egner's house, 1¼ miles south-west of Saucon Valley P. O.

The exposure is small. The rock is contorted and appears to be part of an anticlinal fold. The contortion is no doubt local. The dip is N. 70° W. 30° and N. 75° W. 60°.

96. Gray granitic and dark colored hornblendic (pyroxene) gneiss (granulite) occurs on the Emaus-Coopersburg

road near Mr. Person's house, near the branch road to Limeport, 1⅛ miles south-west of Saucon Valley P. O.

Although the bed rock is exposed, I was unable to obtain the dip of the rock on account of its being weathered and broken.

97. Hydro-micaceous slate and limestone occur loose in the soil in the valley extending north from Limeport.

Loose fragments of the rock are exposed on the roadside. The slate is similar to that found overlying the limestone at Limeport.

98. Light gray granitic gneiss (granulite) occurs loose in the soil on the western slope of the mountain (850 and 770 ft.) east of Limeport. In several places on the Limeport-Center Valley road, in the vicinity of A. Valte's house, light gray feldspathic gneiss (granulite) with grains of magnetite is exposed.*

99. Fine magnetic sand is found everywhere in the wash on the roadsides on the western slope of the mountain east of Limeport.

100. Gray and red quartzite and sandstone occur loose in the soil, 1 mile south-east of Limeport and flanking the mountain 920 and 930 ft. on the north. The rock is probably Mesozoic sandstone.

101. Fine-grained feldspathic gneiss (granulite) is found loose in the soil on the eastern slope of the mountain, west of Center valley.

There are numerous exposures of loose material on the cross-road 1 mile west of Centre valley.

102. An exposure of gray feldspathic gneiss (granulite) with grains of magnetite occurs 1¼ miles west of Centre valley ¼ mile south of Erdman & Cooper's sand pit. (West of summit 680′.)

103. Limestone is exposed in an old quarry ¼ mile south of Erdman & Cooper's sandpit. The limestone appears to cut off from the main limestone area of Saucon valley. The thickness of the rock exposed is about 40 feet.

The limestone is slaty. The dip is N. 60° E. 30°–50°.

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*The gneiss weathers white and has the appearance of sandstone. Some coarse hornblendic (pyroxene) gneiss is also found in this vicinity.

104. Erdman & Cooper's sand pit (mine) is located on the south side of the Centre valley-Saucon Valley P. O. pike one mile west by north of Centre valley.

The limonite is associated with decomposed sandstone and hydro-mica slate. A large amount of silicious matter occurs in the ore.

Decomposed feldspar is found on the surface. The pit is close to the edge of the feldspathic rocks.

105. Coarse gray feldspathic gneiss (granulite) with pink feldspar is exposed on the roadside on the west side of Saucon creek at Centre valley.

The exposure is at the eastern end of the mountain lying between Centre valley and Limeport. The dip is S. 15° E. 30°. The bedding of the rock appears to flatten to the northward and the exposure has the appearance of being part of an anticlinal fold, (south arm.) About 30 feet of rock is exposed.

106. At the southern edge of Centre Valley, west of Saucon creek, limestone is quarried. Several small openings have been made. The quarries are owned by Erdman.

The limestone in the quarry back of Erdman's house appears to rest directly upon the gneiss of the mountain 620 feet. The junction is not visible but from the position of the limestone there appears to be no space between it and the gneissic rocks.

The dip of the limestone is S. 50° E. 25°–30°. Forty feet or more of rock is exposed. In a small quarry ¼ mile south of Centre valley on the west side of the creek the dip is S. 30° E. 25°–30°.

107. Mesozoic breccia of hydro-mica slate and limestone is exposed on the east bank of Saucon creek at the bridge ¼ mile south of Centre valley. The bedding is not well defined but appears to dip S. 20°.

108. Coarse conglomerate and quartzite occur loose in the soil on the road from Locust valley to Erdman & Cooper's sand pit, 1 mile south-west of Centre valley.

The rock is found at the edge of the Mesozoic red shale and apparently rests on the feldspathic rocks.

The probability is that the rock belongs to the Potsdam sandstone.

109. Sill & Jordan's mine is located one mile west of Centre valley ¼ mile south of summit 680 feet and ⅝ mile south of Erdman & Cooper's sand pit.

There are several small openings 20 to 30 feet deep and 10 to 20 feet wide.

The limonite occurs in clay and sand, no slate is visible.

A small lenticular deposit of specular ore occurs in one of the excavations. The limonite is deposited irregularly in the clay and sand.*

The deposit appears to be in the Potsdam sandstone. There appears however to be no Potsdam sandstone between the limestone and feldspathic rocks at Centre valley.

110. A small quarry of Mesozoic red shale is opened on G. Y. Landis' land, ½ mile south of Centre valley, on the west side of Saucon creek ⅛ mile north-west of the Menonite church. The dip is S. 70° W. 30°. A short distance south of the quarry shale is exposed near the creek on the cross-road. The dip is S. 80° W. 15°.

111. Gray feldspathic gneiss (granulite) with pink feldspar is found loose in the soil and on the roadside north-east of Centre valley on the Centre valley-Hellertown road.

112. Chloritic talcose slate (hydro-mica slate) is visible on the roadside, on the cross-road ¾ mile north-east of Centre Valley a few yards south of the Centre Valley-Hellertown road and ¾ mile south of Saucon Valley mill. The exposure is very small in wash-out on the roadside. The dip is S. 60° W. 15°.

113. A small exposure of gray feldspathic gneiss (granulite) occurs east of the road ⅛ mile south of Saucon Valley mills, near a small branch of Saucon creek.

The rock is much weathered and broken. The dip appears to be S. 15° E. 85°.

114. Near the railroad on the north slope of Flint Hill, ⅛ mile mile south-east of Saucon Valley mills, Potsdam conglomerate and sandstone occur loose in the soil.

115. In the railroad cut about 800 feet south-east of Sau-

con Valley mills, a fine grained feldspathic rock is exposed. The dip appears to be N. 15° W. 70°.

Near the south end of the cut quartzite and sandstone are exposed. The dip appears to be S. 15° E. 65°.

The feldspathic rock appears to be a metomorphosed conglomeritic rock, probably belonging to the Potsdam sandstone.

The quartzite and sandstone at the southern end of the cut is unquestionably Potsdam.

116. Wint limonite mine is located one mile north of Centre Valley, ⅛ mile south-west of Saucon Valley mills.

The limonite occurs in lenticular bodies in decomposed sandy hydro-mica slate.

Thin beds of limestone have been found in the mine.

The ore deposit is irregular. The dips observed are W. 10°–15° and S. 45° W 15°. The mine appears to be located near the base of the slates. The ore is very silicious, owing to the large amount of sand which occurs in the slate.

117. Bowlders of light gray feldspathic gneiss (granulite) occur on a noll south of a branch of Saucon creek, one mile south of Saucon Valley P. O., near an old limonite mine.

The rock has scarcely any mica. A small quantity of epidote in small veins and grains of magnetite occur throughout the rock.

The gneiss is loose in the soil.

118. An old limonite mine is located near the base of the mountain, one mile south of Saucon Valley P. O., east of the Emaus-Coopersburg road, south of a branch of Saucon creek, ½ mile east of summit 490′. The mine is abandoned and no exposure can be seen.

No slate appears to exist in the material on the waste-piles. Quantities of fragments of quartzite occur on the surface in the clay. The mine is probably close to the base of the slates overlying the Potsdam (Upper Primal Slates.)

119. Feldspathic gneiss (granulite) with grains of magnetite occurs loose in the soil on the north slope of the mountain, north-west of Limeport and south of Saucon Valley P. O.

120. Three fourths of a mile north-east of Vera Cruz fur-

nace, near the Limeport-Emaus road, at and in the vicinity of J. Christ's house S. of Lehigh mountain, fragments and bowlders of quartzite and brecciated flint occur loose in the soil. The bowlders are confined to the low ground near the southern base of the mountain.*

The rock is similar to that found in the valley between Vera Cruz station and Vera Cruz.

121. At Vera Cruz furnace, and in the vicinity of the furnace on the south slope of the mountain, loose fragments of dark colored, fine-grained feldspathic gneiss (granulite) with grains of magnetite are exposed.

122. Light colored feldspathic gneiss (granulite) is exposed on the south side of a knoll a few yards north of the Vera Cruz station—Vera Cruz road $\frac{1}{4}$ mile north-east of Vera Cruz.

123. Daniel C. Kline's limonite mine is located about 800 feet south-east of the Coleraine Iron Co.'s mine (No. 100) in the south edge of Leipert's gap.

The limonite occurs in decomposed hydro-mica slate. The laminations or dip of the slate is S. 25°-30°. The dip is variable and ranges from S. 10° W. to S. 10° E.

124. Hildegast magnetic mine is located on the south-western end of Lehigh mountain, east of Shelley's saw-mill, about two hundred feet above the bottom of Leipert's gap.

The mine is worked to a depth of 100 feet. From 3 to 5 feet of ore is exposed in the workings.†

In a slope sunk on the bed the feldspathic gneiss (granulite) is thoroughly decomposed to a depth of 40 feet.

The dip of the bed is S. 20°–30° E. 55°–60°.

The rock is somewhat micaceous in places, though usually composed wholly of quartz and feldspar, (granulite.)

The magnetite is associated with quartz principally. A small amount of iron pyrite occurs in the ore.

The more micaceous gneiss becomes shaley and splits in thin scales when weathered.

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* There appears to be no Potsdam sandstone in place in this vicinity. The formation unquestionably exists in this depression.

† The mine is not in operation, and the above figures were given to me by one of the owners.

125. Two thirds of a mile north-east of the toll-gate on the Millerstown-Shimersville pike rusty Potsdam quartzite and flint breccia cover the mountain terrace. Large quantities of loose débris occur in the soil in the vicinity of H. Desh's house (500) on the Leipert's gap road.

126. West of Leipert's gap ½ mile, ¼ mile west of T. Buskirk's house, just north of summit 710′ sandy decomposed feldspathic gneiss (granulite) is exposed on the roadside. Several small excavations have been made on the roadside.

Seams occur through the mass which have a dip E. 60°. These are probably cleavage planes.

The decomposed rock is exposed to a depth of about ten feet from the surface.

127. Potsdam quartz, conglomerate, sandstone, and flint breccia occur loose in the soil on the Shimersville-Vera Cruz road at and near the school-house, ⅛ mile north-east of Shimersville, south of summit 820′.

This deposit is continuous with that noted on the Shimersville-Emaus road near summit 820. (See § 74.)

128. Gray and dark colored gneiss (granulite) occurs on the Shimersville-Vera Cruz road a short distance east of the school-house, on the southern slope of the mountain 830′. Some pyroxene and epidote occur in the rock.

129. Just east of Shimersville angular fragments of Potsdam quartzite and sandstone cover the north slope of the mountain 850 and 930 feet.

130. The terrace ⅛ mile north of summit 930 feet, one mile east of Shimersville is covered with large angular blocks of thinly bedded Potsdam sandstone and quartzite.

131. One quarter of a mile north-west of summit 930′, one mile east of Shimersville, several trials pits have been sunk on decomposed specular ore.

The openings are a few rods west of the road which crosses the mountain east of the summit.

The ore is slightly magnetic. The openings indicate a strike N. 10° E.–S. 10° W. Nothing is visible in the openings and the position of the ore cannot be ascertained. It is undoubtedly at or near the base of the Potsdam sandstone.

132. Trap (dolerite) of greenish color is exposed on the road one third mile north of the P. V. railroad, about ½ mile west of Dillinger Station, on summit 790′.

133. Decomposed feldspathic gneiss (granulite) and fine grained micaceous gneiss occur on the Vera Cruz-New Zionsville road, ½ mile west of Dillinger station.

At one point on this road, about 800′ north of the railroad, ¾ mile south-west of Dillinger station, decomposed feldspathic gneiss occurs in place on the roadside. The dip is S. 10° W.±90°.

134. The southern slope of the mountain, ½ mile south-west of Dillinger Station, near the railroad, is covered with fragments of Potsdam quartzite and flint breccia.

135. Decomposed gray felspathic gneiss (granulite) occurs on the north slope of the mountain 810′, one mile east of New Zionsville, north-west of Dillingersville.

136. A few rods north-west of Vera Cruz station at the base of the mountain gray granitic gneiss (granulite) is exposed in an old quarry. The rock is much broken and the dip could not be obtained.

137. Bader magnetite mine is located ¼ mile north-west of Vera Cruz station, on the southern slope of Lehigh mountain, at about 700′ elevation.

The dip of the bed is about S. 15° E. 60–70. The thickness of the bed varies from 4 to 7 feet. The ore occurs in quartz and feldspar rock (granulite.)

138. Quantities of magnetic sand occur on all the roadsides on the southern slope of Lehigh mountain.

The magnetite is derived from the decomposed granulite.

The largest quantity of magnetic sand was observed ⅛ mile east of Vera Cruz station, on the road leading to the Vera Cruz furnace.

139. There are numerous trial pits and small openings on magnetic ore beds on the southern escarpment of Lehigh mountain in the vicinity of Vera Cruz station.

The openings appear to be on three distinct horizons or beds.

The lowest openings on the mountain side, which are geologically the highest, are at an elevation of about 700′.

The upper openings are at an elevation of 800′. A few intermediate openings indicate a bed about half way between the upper and lower beds.

The principal openings are 800′ north and 12′ to 1600′ north-east of Vera Cruz station.

Operations are suspended at all the openings. Pyroxene and black mica occur with the ore. Pyrite occurs at some of the openings.

140. Several openings (trial pits) have been made on magnetic beds about 1,600 feet north-east of Vera Cruz furnace on the north-east end of a spur of the mountain at an elevation of 600 feet.

The ore is associated with quartz and feldspar gneiss, (granulite.) No exposures occur, and the pits are abandoned.

141. Loose fragments gray feldspathic and fine grained, dark colored micaceous gneiss (granulite) with epidote and pyroxene, cover the southern escarpment of Lehigh mountain in the vicinity of Vera Cruz station and furnace. The rock is visible on the road which crosses the mountain. No ledges of the rock can be found,

142. Decomposed feldspathic gneiss (granulite) is exposed along the Vera Cruz-Lanark P. O. road, between J. Christ's and J. Bleiter's houses, at the south-eastern base of Lehigh mountain.

143. South of the Vera Cruz-Lanark P. O. road, in the vicinity of J. Christ's and J. Bleiter's houses, fragments of Potsdam quartzite and flint breccia occur loose in the soil.

144. At Lanark P. O. limonite occurs in decomposed slate and clay. A small opening has been made just north of the P. O.

145. Enormous bowlders and blocks of gray feldspathic gneiss (granulite) cover the southern escarpment of Lehigh mountain near the Lanark-Mountainville road, between E. Bender's house and the mountain summit.

The rock often presents a banded appearance. Quantities of magnetic sand occur on the roadside.

146. South and south-west of Bowers' rock, (1,010′,) north

of Lanark P. O., large blocks of gray felspathic gneiss (granulite) cover the escarpment of the mountain.

147. The whole surface of the mountain in the vicinity of Bowers' rock (1,010′) is covered with large blocks and loose fragments of gray gneiss. Some of the rocks are 20 feet high and are evidently remains of broken ledges. Usually grains of magnetite occur through the feldspathic rock.

Some pyroxene occurs in the rock north of Bowers' rock.

About 1,800 feet west of Bowers' rock the gneiss appears to dip S. 10° W. 30°.

148. The entire southern escarpment of the mountain between Bowers' rock and Colesville is covered with loose fragments and blocks of gray feldspathic gneiss, (granulite.) Usually bands or lines of stratification are visible. The banded appearance is due to small amounts of mica or hornblende (pyroxene.)

149. Friedensville zinc mine.

The mine is located at Friedensville about one mile west of Bingen station on the N. P. R. R.

The zinc blende is associated with iron pyrite. It is disseminated through limestone. The limestone has the appearance of having been broken and cracked, and the interstices filled with infiltrated blende and pyrite. The mass has somewhat the appearance of a breccia. The zinc blende is not confined to one bed or horizon; but extends through a vertical thickness of 30 or 40 feet in some places, while at other points in the mine the infiltration of blende appears to be confined to a vertical thickness of 10 to 20 feet.

The mine is worked to a depth of 250 feet on the slope of the bed.

The excavations are very large and extend along the strike more than a thousand feet.

The dip of the limestone is S. 5°–10° E. 30°–35°.

150. On the Friedensville-Bethlehem road at Colesville loose fragments of decomposed feldspathic gneiss are exposed on the east slope of the mountain.

151. Loose fragments of Potsdam quartzite and sandstone occur on the Friedensville-Bethlehem road between Coles-

ville and Seidersville. The rock is found close to the eastern base of the mountain near Black creek.

152. The eastern slope of the mountain between Colesville and Seidersville is covered with loose fragments and blocks of gray feldspathic gneiss, (granulite.)

Several small trial pits have been opened on magnetic ore. The beds are insignificant. The magnetite occurs in granulite.

153. Decomposed feldspathic gneiss is quarried on the south-western edge of the mountain south-east of Lehigh furnace, 1¼ mile east of Fairview.

The rock is thoroughly decomposed and the bedding obliterated. The dip is probably S. 10° W. ±90°.

154. An extensive ledge of gray feldspathic gneiss (granulite) is exposed on the northern slope of the mountain, ¼ mile east of Lehigh furnace, south of the Lehigh river.

Coarse pink feldspar occurs in the rock. The ledge is in some places 50 feet high. The dip of the rock is S. 60° E. 40°–60°.

The exposure of bed rock at this point is due to the sharp curve of the Lehigh river to the eastward having washed the loose débris from the face of the mountain.*

155. The entire northern slope of the mountain on the south side of the Lehigh river between Allentown and Bethlehem is covered with large angular blocks and fragments of gray feldspathic gneiss.

The rock appears to be decomposed to a considerable depth.

156. Potsdam sandstone and quartzite is exposed at the western end of the mountain, south of Lehigh furnace, south-east of Allentown.

About 20 feet of rock is visible at a quarry.

The dip is W. 25°–35°.

157. Potsdam sandstone and quartzite is quarried in several places on the north side of the mountain south of the Lehigh river about ¾ mile east of Lehigh furnace. The rock is thinly bedded, of gray color and usually composed of fine sand.

* Ice may have had an influence in clearing the surface, but no scratches or striæ were observed.

Granite bowlder, W.N.W. from Topton station.

About 20 feet of rock is exposed.

The dip is N. 20° W. 30°.

158. On the north side of the Lehigh river, between Allentown and Bethlehem, a narrow belt of gray feldspathic gneiss (granulite) forms a prominent ridge.

The river flows along the base of the ridge for a distance of about $\frac{3}{4}$ of a mile.

Large quantities of loose fragments and blocks of gray feldspathic gneiss cover the southern slope of the ridge near its western end.

The northern slope of the ridge is flanked by Potsdam sandstone. (Rogers, p. 96.)

159. West of South Bethlehem on the cross-road west of summit 660 ft. large blocks and bowlders of gray granitic feldspathic gneiss (granulite) are exposed.

160. A narrow belt of gneiss forms a ridge two and a half miles north of Bethlehem.

The ridge is in general parallel to the course of the Lehigh river.

The gneiss can be traced from the Bethlehem-Shoenersville road to the Bethlehem-Nazareth pike.

The greatest elevation of the ridge is at its eastern end.

The two most prominent points on the ridge are Pine Top 460 ft. and Quaker Hill 530 ft. Limestone surrounds the ridge. (Rogers, p. 96.)

Decomposed feldspathic gneiss is quarried on the south-eastern slope of Pine Top. The north-western slope of Pine Top is covered with loose fragments of gray feldspathic gneiss. The rock is usually fine grained, and is in every respect similar to the gneiss of the Lehigh mountain.

161. The entire northern slope of the mountain south of South Bethlehem is covered with loose débris of gray and dark-colored feldspathic gneiss, (granulite.)

Large quantities of bowlders and fragments of gneiss occur on the Friedensville-Bethlehem road, on the north slope of the mountain south of South Bethlehem.

Near the summit of the mountain, on the north side, dark-colored quartzose gneiss occurs on the roadside.

162. Loose fragments of gray feldspathic gneiss (granulite)

are visible on the road crossing the eastern end of the mountain, south-east of Bethlehem near Saucon creek, quantities of magnetic sand occur on the roadside.

163. The N. P. R. R. exposes the gneissic rock of the mountain in a cut just north of Saucon creek, south-east of South Bethlehem. The dip is S. 50°.

164. A short distance east of the N. P. R. R., north of Saucon creek, south-east of South Bethlehem, bowlders of Potsdam quartzite and sandstone are exposed in the Bethlehem-Shimersville (on the Lehigh) road.

165. Bowlders of Potsdam quartzite and flint breccia are visible on the southern slope (lower terrace) of the mountain 1½ mile north-west of Hellertown.

166. On the south bank of the Lehigh river opposite Freemansburg, coarse feldspathic gneiss with pink feldspar is exposed on the roadside. The dip is S. 40°–55°.

167. Along the southern base of the mountain east of Shimersville (on the Lehigh) and south-east of Freemansburg gray quartzose feldspathic gneiss (granulite) occurs loose in the soil. The rock is usually banded and resembles that found just south of Bethlehem.

An absence of any quantity of large blocks and bowlders is noticable on the southern side of this mountain.

168. On the west slope of the mountain, 1½ mile east of Shimersville (on the Lehigh) loose bowlders of gray feldspathic gneiss (granulite) occur. Grains of magnetite and some mica and pyroxene are found in the rock.

169. Just east of summit 730′, 2½ miles east of Shimersville (on the Lehigh) gray banded gneiss is found loose in the soil. Epidote and hornblende (pyroxene) occur in the rock.

170. On the road north-east from Lower Saucon, P. O., south ¼ mile of summit 680′, the soil is very ferruginous and in some places quite red. Loose fragments of quartzose feldspathic gneiss occur in the soil.

171. South-west of Lower Saucon P. O. on the south slope of the mountain east of G. Kuauss' house loose blocks and bowlders of granitic gneiss occur.

172. Loose bowlders of Potsdam quartzite, conglomerate

and sandstone occur in the soil on the north slope of the mountain just south of Lower Saucon Union Church.

173. Weber's limonite mine is located about ½ mile southwest of Lower Saucon Union church.

The limonite occurs in decomposed slate and clay.

174. About two feet of ore was found in a trial pit one mile south of Lower Saucon Union church, 1mile northeast of Hellertown on the west end of the mountain at 700 ft. elevation.

The ore occurs in quartzose feldspathic gneiss (granulite.)

175. Limonite is mined ¾ miles east of Hellertown at the head of a branch of Saucon creek which flows through Hellertown. Several openings have been made.

The Crane Iron Co. have a shaft 67 ft. The ore occurs in clay and decomposed slate.

176. At Trinity church on the Lower Saucon P. O.-Springtown road 2½ miles east of Hellertown Potsdam sandstone and conglomerate is exposed on the south side of an old limonite mine.

The mine is full of water but it is evident that the sandstone formed the foot wall of the ore.

About 15 feet of sandstone is exposed. The dip is N. 10° W. 70°.

177. A few rods south of the Potsdam sandstone at Trinity church 2½ miles east of Hellertown feldspathic gneiss is exposed on the Lower Saucon P. O.-Springtown road.

The dip is obscure but may be N. $\pm$ 90°.

178. Emerick's limonite mine is located ¼ mile west of the Lower Saucon P. O.-Springtown road south of summit 820′ 2½ m. east of Hellertown at the head of a branch of Saucon creek which flows into Saucon creek just south of Hellertown.

The limonite occurs in decomposed slate.

179. The southern escarpment of the mountain 820 ft. two miles east of Hellertown is covered with blocks and fragments of dark gray feldspathic gneiss, (granulite.)

On the western slope of this mountain, west of A. Bauder's house, bowlders of Potsdam quartzite and flint breccia occur in the soil.

180. Potsdam conglomerate and slate occur on the road 1 mile south-east of Hellertown, on the south-western slope of the mountain 820 feet.

181. About 1 mile south of Hellertown, on the Hellertown-Springtown road, at S. Kessler's house, decomposed, thinly bedded, micaceous feldspathic gneiss is exposed on the roadside. The dip is S. 50°–65° W. 50°.

182. In the railroad cut a few rods north of the Centre Valley railroad station, feldspathic gneiss (granulite) is exposed. Pink feldspar is predominant. The rock is much broken, and the lines of bedding doubtful. The dip appears to be S. 10° E. 20°.

183. Potsdam sandstone is exposed on the west end and south side of the ridge, (650′,) known as Flint Hill, west of Spring valley. The exposures are about 1,600 feet east of Saucon valley mills. The rock is exposed close to the Spring Valley-Saucon Valley Mills road. About 10 feet of rock is exposed. The dip is N. 50° W. 20°–25°.

184. Magnetic ore has been mined near G. Seiple's house, 1 mile west of Spring valley, south-west of the summit 650 feet. The mine was worked by Egleberger & Frey.

Several trial pits have been sunk on the southern slope of the hill in the vicinity of the old mine, close to the Spring Valley-Saucon Valley Mills road. The magnetite is associated with quartz and feldspar, black mica, and some pyroxene.

The feldspathic rock is considerably decomposed.

185. One fourth mile west of Spring valley, south of summit 620 feet, close to the Spring Valley-Saucon Valley Mills road, a quarry is opened in decomposed feldspathic gneiss, (granulite.) The cleavage dip is N. 35° E. 80°. The dip of the rock cannot be ascertained.

186. Quartzose feldspathic gneiss (granulite) with grains of magnetite is exposed at and in a tunnel driven into the hill on the north side of the brook at Spring valley.

The dip is S. 15° W. 45°. The cleavage is N. 40° E. 60°–80°.

187. Potsdam quartzite and flint breccia occur loose in the soil on the slope (400′ to 470′) south of Spring valley.

188. Half way between Spring valley and Leithsville decomposed feldspathic gneiss occurs on the northern slope of small well-defined ridge (560′.)

189. A quarter of a mile south of Leithsville limestone has been quarried on W. F. Detwiler's place.

The rock is thinly bedded and bluish color, about ten feet of rock is exposed. The dip is S. 20° E. 20°.

The limestone appears to be overlaid by Mesozoic sandstone.

190. About one mile west by south of Springtown, west of Geisinger's mine, white sandstone, conglomerate and greenish sandy slate occur. The white sandstone is visible on the surface of the ground. The rock is probably Potsdam.

191. Brecciated limestone occurs about three quarters of a mile south-west of Springtown south-west of Geisinger's mine.

It forms a ridge along which the ragged edges of the partially decomposed rock are visible. The ridge can only be traced a few hundred yards. Its direction is N. W. and S. E. The dip of the rock where exposed in the road appeared to be S. 10° W. 50°.

192. Geisinger's limonite mine is located about one half mile south-west of Springtown near the main road.

The limonite is found in decomposed slate and clay. The mine is not working. The excavation is at a depth of about 25′.

193. Potsdam sandstone occurs at the mill ¾ mile east of Springtown. The rock is exposed near this mill on the roadside and it forms a prominent ridge extending northeastward along the base of which Guck's creek flows. The dip of the rock at the mill is N. 30° W. 10°–12°. On the ridge the dip is N. 40° W. 10°.

194. Slaty limestone is found close to the Potsdam sandstone north of the mill ¾ mile east of Springtown. The dip of the limestone in an old quarry is S. 30° E. 20°.

195. Aiken's limestone quarry is located east of the hotel at Springtown and near the church. The limestone is bluish gray color thin-bedded about 25′ of rock exposed.

The dip is S. 30° W. 25°.

Along the northern side of the quarry the limestone lies directly against sandstone which appears to have the same dip as the limestone. The line of fault is about S. 60° W. and N. 60° E. ± 90°.

196. North-east (1200 ft.) of the Springtown church limestone has been quarried. The opening is small. The rock is bluish color and massive at the base, slaty at top of quarry. About 25′ of rock is exposed.

The dip is irregular to the north 15°, (Roger's, p. 99.)

197. North of Springtown near the Springtown-Lower Saucon P. O. road a broken ledge of gray granitic gneiss with magnetite (granulite) is exposed along the base of the mountain. The dip appears to be S. 10° E. 60°.

198. Loose fragments of gray feldspathic gneiss (granulite) occur on the north slope of the hill (530′) ¼ mile south of Springtown.

199. Gray granitic gneiss occurs along the Springtown-Stout's P. O. road on the southern slope of the mountain.

Bowlders of gray granitic gneiss occur on the summit (900′) of the mountain between Springtown and Stout's P. O.

200. Hornblendic (pyroxene) and feldspathic gneiss with pink felspar occur on the northern slope of the mountain north of 820′ and 790′ summits on the Springtown-Stout's P. O. road near J. Fulmer's house.

201. Pyroxene and feldspathic gneiss occur on the same road about ¾ mile south-west of Stout's P. O.

202. Feldspathic and hornblendic (pyroxenic) gneiss with epidote occurs near D. Raub's house on cross road just south of Stout's P. O.

203. Gray granitic gneiss with grains of magnetite and hornblendic (pyroxene) gneiss cover the northern slope of the mountain (760′ and 670′) south of Stout's P. O. Quantities of magnetic sand occurs along the roadsides.

204. Hornblendic and feldspathic gneiss occurs on and close to the county line north of Durham P. O., south of summit 670′. The rock is found loose on the mountain side.

205. One third mile north of Durham Union church south of summit 600′ gray and pink feldspathic gneiss with epidote occurs loose on the roadside. Pyroxene and banded feldspathic rock with epidote also occur on the roadside.

206. South of the Durham Union church at 400′ hydromica slate and slaty limestone occur. The dip appears to be S. 25° E. 20.

207. Just north of Durham P. O. at the foot of the mountain massive limestone (15 ft.) overlaid by shaly beds (10 ft.) is exposed in a quarry.

The dip is S. 60° E. 30°.

208. ¼ mile below Durham furnace on the west bank of the Delaware river, massive gray-banded granitic gneiss (granulite) forms a prominent bluff. The rock contains pink feldspar and some epidote.

The dip is S. 20° E. 50°.

209. Just north of Monroe on the west bank of the Delaware river gray and dark-colored hornblendic pyroxene felspathic gneiss is exposed.

The cleavage planes traverse the mass in all directions and the dip is doubtful S. 30° E. 10°–15°.

At Monroe Mesozoic sandstone slate and brecciated conglomerate occur sixty feet or more of rock is exposed at the village. The dip is N. 40° W. 20°. About ten feet of red shale is exposed near the road above which 18 inches of conglomerate occurs. About twenty feet above this bed (18″) a bed of about 10 feet of breccia is exposed.

211. On the Monroe-Durham road loose fragments of gray feldspathic and hornblendic gneiss occur on the slope east of summit 370 ft. near Monroe.

212. Loose bowlders of Potsdam quartzite and flint breccia occur on this road south-west of summit 490′ south of Mine hill.

213. Surface mine or Mine Hill mine.

The mine is located just south of summit 490′ of Mine hill.

About 18 feet of ore is workable on the surface. The bed pitches S. 60° E. 40° and (E. 30°.)

The ore is red hematite and somewhat magnetic. The

thickness of the bed is variable. The ore is mixed with quartz principally and has a mottled appearance. It appears evident from the proximity of the Potsdam sandstone that this ore is between the Potsdam sandstone and the gneissic rocks.

214. About one quarter of a mile south-west of the Surface mine east of a branch of Guck creek, due south of Durham P. O. a ledge of Potsdam sandstone is exposed. The rock is much broken and weathered and it is impossible to determine the dip. Probable dip is S. 5° W.+10°. (Rogers p. 99.)

215. Gneiss is exposed along brook one mile south of Durham P. O. and west of summit 530′.

The dip is S. 45° E. 25°.

216. Slate and slaty gneiss is exposed south-west of the summit 530′ and about 1 mile S. of Durham P. O. near Geisinger's mill. Fine-grained feldspathic gneisses exposed near the dam. The dip is S. 10° W. 15°.

The slaty rock has the appearance of metamorphosed slate.

217. About one and a half mile south-west by south of Durham P. O. the southern slope of the mountain 570′ is covered with loose fragments of hornblendic (pyroxene) feldspathic gneiss, (granulite.)

218. About half-way between Durham P. O. and Springtown, limestone is quarried on a noll 350′. The limestone is massive and bluish color, much broken and cracked. The dip is S. 70° E. 30°. About 18′ is exposed in the quarry.

219. The entire southern side of the valley between Durham P. O. and Springtown is covered with loose blocks and bowlders of Potsdam sandstone, quartzite, and flint or flint breccia.

220. The Potsdam forms a prominent ridge east by north of Springtown on the N. side of the valley of Guck creek.

221. The southern slope of the mountain north-east of Springtown is covered with loose fragments of fine-grained gray laminated feldspathic gneiss with magnetite.

222. Brotzman & Pearson's limonite mine is located on the southern slope of the mountain about 450′ elevation

south-east of summit 850′, and about half-way between Durham P. O. and Springtown. The limonite is overlaid by 6 to 10 feet of débris from the mountain. No slate is visible in the mine. The openings small and not over 15 feet deep.

223. Limestone quarry south of W. S. Long's quarry on road ⅛ mile north-west of Durham, massive and shaley limestone is exposed. Dip ? N. 10° E. 30°.

224. Limestone is exposed at north-eastern base of Rattlesnake hill on roadside. D. S. 30° E. 20°.

225. Limestone is exposed in a quarry ¼ mile N. W. of Durham Furnace on east side of creek. Dip S. 15° E. 30°.

226. Rattle-snake mine is located on the north slope of Mine hill near the summit. The mine is opened by two slopes driven on the bed. The slopes dip S. 10° E. and S. 10° W.

The dip of the bed appears to be S. 20° W. 40°. The bed is undulating and variable in thickness. From 5 to 15 feet of ore is found. The main slope is 400 feet deep. Three levels have run from the slope.

Much of the ore is fine-grained and quite pure. The ore is associated with quartz and feldspar.

227. New tunnel is located a short distance east of Durham P. O. The tunnel runs 2,000 feet into the mountain, (Mine hill.) The direction of the tunnel is nearly due south. The ore bed is cut under summit 490 feet. The workings are on two levels. The ore is evidently the same as that found at Rattle-snake mine.

228. Hollow tunnel, located on the east side of Mine hill ½ mile north-west of Durham furnace. The ore is cut at 526 feet from entrance of tunnel. The bed is the same as developed at Rattle-snake mine. The rock is gray and rusty and dark colored feldspathic gneiss (granulite) with grains of magnetite.

229. North of Rattle-snake hill large rounded bowlders of Potsdam quartzite occur along a branch of Guck creek. The deposit has the appearance of a glacial deposit.

230. On the southern slope of Bougher's (Bucher's hill) hill, 1 mile N. of Rieglesville, no exposures occur. A few

loose blocks of feldspathic gneiss occur associated with quartzite bowlders. Probably the Potsdam extends along the southern base of the mountain, but the formation cannot be defined.

231. Opposite Bougher hill, on the New Jersey side of the Delaware river, a bold bluff of granitic rock (granulite) faces the river. The dip is S. 20° E. 30°. The bluff is over two hundred feet high, and the exposure is a prominent feature from the Pennsylvania side.

232. Along the eastern base of Bougher hill close-grained hornblendic (pyroxene) feldspathic and pink quartzose feldspathic and granitic gneiss (granulite) is exposed.

In many places the ledge is very prominent and overhanging. The dip is S. 40° E. 30°. About 1,500 feet of rock is exposed.

The mountain has the appearance of a monoclinal.

233. Limestone in the vicinity of Uhlersville is exposed extensively in the quarries.

The dip is S. and S. 10°–15° E. 60°–80°.

The dip would be in accordance with a synclinal fold. Ripple marks are exposed on an extensive scale at a quarry just below Uhlersville. (Rogers', p. 99.)

234. At Raubsville on the west bank of the Delaware river, about five miles below Easton, gray gneiss with some black mica and pyroxene is exposed on the roadside and on the mountain slope.

The dip is S. 40° E. 55°.

235. Slaty limestone is exposed near the canal, a short distance north of Raubsville and north of the gneissic belt. The dip is N. 30° near the southern edge of the limestone belt at an exposure near the center of the limestone area on the west bank of the Delaware river east of the summit 370′. The dip is S. 40° E. 40°. (Rogers, p. 99.)

236. The southern slope of the mountain south-west of Raubsville is covered with loose blocks and bowlders of gray and banded feldspathic gneiss, (granulite.) Some mica occurs in the rockpyroxene is also present.

237. Enormous blocks of gray fedlspathic rock occur about one mile west of Raubsville on the S. slope of the mountain.

Some of the blocks are fifteen feet in length and eight or ten feet in diameter.

238. Lerch limonite mine is located about 2½ miles west of Raubsville on the southern slope of the mountain at an elevation of about 500′, south-east of elevation 940′ of Hexenkopf hill.

The limonite occurs in decomposed slate. The ore is mined through two shafts about twenty feet deep.

239. Three quarters of a mile south-east of Hexenkopf hill, 1030′ summit, just north of the 700′ summit quartzose gneiss with epidote and pyroxene occurs loose in the soil. Some of the rock has a greenish color due to the epidote.

240. Gray and dark colored gneiss (granulite) occurs on the north slope of Hexenkopf hill. Magnetic sand is found on the roadside. Epidote and pyroxene occur in the loose bowlders along the road which crosses Hexenkopf hill between the summits 1030′ and 940′. Much of the rock has a banded appearance. Very little mica is found in any of the rock.

241. Indications of limonite in decomposed slate occur in the soil about one mile due south of Hexenkopf Hill summit 1030 ?, northwest of Stout's P. O. east of the summit 750 feet. The elevation is about 550′ and on a range with the limonite deposits at Lerch's mine.

242. On the southern slope of Hexenkopf Hill summit 1030′ gray banded gneiss occurs loose on the surface. Epidote and pyroxene is prevalent throughout.

There are no exposures of the rock in place. The probability is that the dip is to the southward.

243. On the northern slope of Hexenkopf hill just west of summit 940′ on the roadside near a house at an elevation of 830′ gray gneiss is exposed. The dip is S. 40° E. 50°.

244. Along the entire crest of the mountain north-east of Hexenkopf hill there are no exposures of rock, and but few loose bowlders in the soil. The crest of the mountain is cultivated pretty generally. Along the southern slope of the mountain loose bowlders occur.

245. At the western extremity of Morgan's hill, and south of Glendon, gray feldspathic gneiss is exposed on the road-

sine near the Glendon Iron Co.'s mine (No. 41.) The dip is S. 60° E. 70°.

246. Along the entire northern terrace of Morgan's hill, south of South Easton, limonite is mined. The ore occurs in decomposed slate and clay. The workings are almost continuous for a distance of about two miles.

247. Near the eastern end of Morgan's hill, close to the Delaware river, about one mile below the confluence of the Lehigh river, massive and shaley limestone is exposed on the river road. The dip is N. 15° W. 45°+.

Close to the river, near the edge of the Potsdam sandstone, the dip is N. 75° W. 30°.

248. Potsdam sandstone is exposed on and near the river road about one mile south-east of the mouth of the Lehigh river, at the northern base and eastern extremity of Morgan's hill. The dip appears to be S. 40° E. 45°.

249. The eastern slope of Morgan's hill, close to the Delaware river, is covered with loose débris of grayish, banded feldspathic cork, (granulite.)

250. High bluffs of feldspathic gneiss (granulite) are exposed on the southern side of Morgan's hill south and S. W. of summit 760′.

The exposures are visible along the river road, (South Easton-Raubsville road.) The rock has a variable dip of S. 20° W. 65°-S. 10° E. 70°, S. 10° E. 65°.

251. Along the southern escarpment of Chestnut hill steatite and serpentine extend from the Delaware river to a point about one half mile west of Bushkill creek. The belt has a width of about four hundred feet.

The serpentine and steatite has generally a greenish color.

Associated with the steatite massive, coarse quartzose feldspathic rock (granulite) occurs.

The rock is different in character from the feldspathic rocks of the gneissic belt which forms the mass of Chestnut hill. The feldspathic rock associated with the steatite belongs evidently to the steatite belt.

The apparent dip of the steatite and serpentine in the quarries close to the Delaware river is S. 70° W. 60° and S. 10° E. ±90°.

The dip S. 70° W. 60° is in all probability erroneous. There are two quarries close to the Delaware river worked by J. T. Williams.

The steatite and serpentines of this belt appear to be equivalent to the slates overlying the Potsdam sandstone, (Upper Primal slates.) I see no explanation for the alteration of the hydro-mica slates of the Upper Primal into steatite and serpentine in this locality. (Rogers, p. 94–5.)

252. At the eastern extremity of Chestnut hill close to the Delaware river extensive exposures of micaceous feldspathic gneiss and granulite occur.

High bluffs of rock occur along the river road. The dips observed are S. 60° and S. 40° E. 70°. The dip S. 60° is probably a local contortion.

253. Light green serpentine and steatite is exposed on the roadside on the east bank of Bushkill creek at the southern edge of the gap through Chestnut hill about one mile and a half west of the Delaware river.

The dip is S. 15° E. 60°.

254. Extensive exposures of fine-grained and coarse granulite (quartz and feldspar) with grains of magnetite is exposed along Bushkill creek in the Chestnut Hill gap.

Pink feldspar with epidote is prevalent in the coarser-grained rock.

About five hundred feet of rock is exposed in the gap.

The dip observed are S. 15° E. 40°, S. 20° E. 45°, S. 15° E. 35°.

255. Just north of Chestnut hill at the Bushkill creek gap limestone is found directly against the feldspathic rocks.

The limestone dips N. 25°.

The actual junction between the two formations is concealed, but the distance between them is not over twenty-five feet.

It is impossible from the direction of the dip of the limestone for the Upper Primal slates or Potsdam sandstone to occur on the north side of Chestnut hill at Bushkill creek, and as there is no trace of the slates between Bushkill creek gap and the Delaware river, it is evident that the

same structure extends along the north base of Chestnut hill.

I am unable to judge whether a fault or non-conformability exists on the north side of Chestnut hill, but if the talcose and serpentine rocks flanking the hill on the south are the representatives of Upper Primal slates, the structure on the north side of the hill is explained by a fault; otherwise some trace of the slates would be found.

The probable structure of Chestnut hill is an overturned anticlinal having the gentle slope of the fold on the south side.

A fault on the north side of the axis of this anticlinal would bring the limestones into the position in which they are found against the feldspathic gneisses and bury the Potsdam sandstone and Upper Primal slates.

The similarity throughout the Durham hills region of the feldspathic gneisses would favor an overturned anticlinal structure. Rogers, p. 101.

The observed dips of the gneissic rocks are to the southward.

A series of faults bringing up the same series of gneissic rocks would not explain the occurrence of the Potsdam sandstone and limestones in places and positions where they are found. Usually more loose blocks of feldspathic gneiss are to be found on the northern slopes of the mountains than on the southern slopes. This fact indicates a steeper dip of the measures on the north side of the mountain or a monoclinal structure. Either structure would produce the same result.

The magnetic iron ores in southern Lehigh and Northampton counties are found interstratified with the quartz and feldspar rocks (granulites.)

The magnetite is widely disseminated throughout the rock, and is found to be present at almost all localities where the older crystalline rocks are exposed.

The crystalline rocks are composed principally of quartz and feldspar. In some cases small amounts of dark colored

mica and pyroxene occurs through this rock, occasionally particles of mica and magnetite are found together. Much of the rock is composed wholly of quartz and feldspar.

The magnetite is generally more or less mixed with quartz and feldspar, although occasionally portions of the deposits are met with which are quite pure.

The magnetite beds are always parallel to the bedding of the rock. They are very variable in thickness.

The principal mines are at the south-western end of Lehigh mountain, near Vera Cruz, on the western and southern slope of the mountain, and also on Mine Hill, just east of Durham P. O., near the Delaware river, in Bucks county. A large number of trial pits have been sunk along the southern side of Lehigh mountain; but evidently with no flattering results, as operations are everywhere suspended.

The only mineral of economic value found in the gneissic measures, with the exception of magnetite, is corundum. See § 72.

The locality is a short distance north of Shimersville, in Lehigh county. It is my opinion that the amount of corundum at this locality is not great.

The corundum occurs in feldspar in proximity to feldspathic and hornblendic gneiss.

There are no exposures of the feldspar with corundum, but I judge it occurs in vein in the gneissic rocks.

Potsdam.

Potsdam sandstone, quartzite, and flint breccia occur in a number of places throughout the area. The exposures of Potsdam sandstone in place are few. Usually loose fragments of the rock occur on the surface.

The sandstone is often feldspathic and the rock decomposes rapidly.

The feldspar is no doubt derived from the disintegration of the underlying gneissic rocks (granulite.)

The Upper Primal slates are often found where no trace of the Potsdam sandstone can be found. This apparent absence may be due to the fact that the sandstone is usually not thick and might readily be overlooked.

The thickness of the Potsdam appears to be usually between 25 and 50 feet. At one place, just north of Hossensack, the thickness of the Potsdam appears to be about 150 feet, but this thickness may be erroneous.

Specular Ore.

The specular ore of Shimersville, New Zionsville, and Durham, appear to occur at or near the base of the Potsdam sandstone. The ores at Shimersville and New Zionsville are associated with chloritic slates which may be the equivalent of the Lower Primal slates.

Limonite.

All the deposits of limonite throughout the district examined occur in decomposed hydro-mica slates and clay Upper Primal slates and are geologically over the Potsdam sandstone. Near Emaus, (§ 89,) the hydro-mica slate is seen adhering to the upper bed of the sandstone. Two and a half miles east of Hellertown (§ 176) Potsdam sandstone forms the foot wall of an old limonite mine.

These are the only two localities where the Potsdam sandstone was seen in direct contact with the Upper Primal slates.

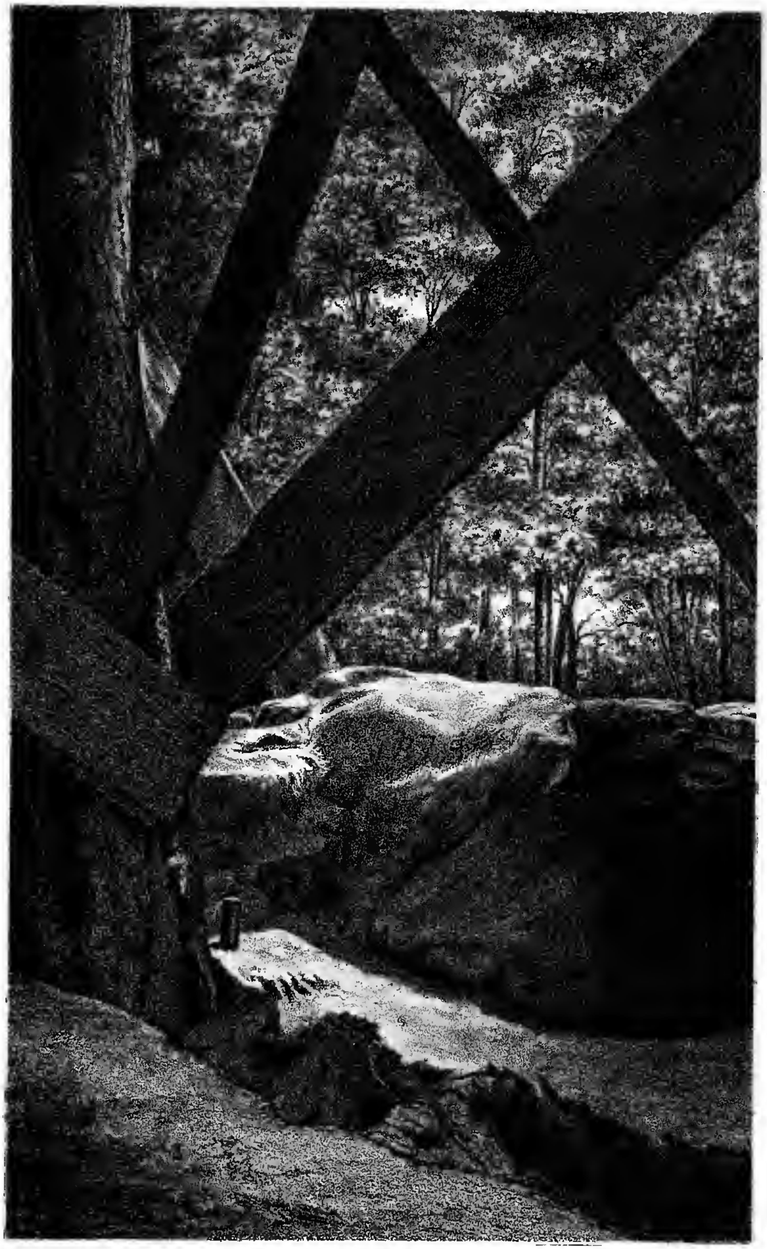
On the southern slope of Chestnut hill the Upper Primal slates (hydro-mica slates) appear to have been altered into steatite and serpentine (§ 251.) No limonite occurs on the flanks of Chestnut hill.

Limestone.

The disposition of the limestone is irregular. The principal limestone area is in the Saucon valley, south and south-east of Lehigh mountain. Along the northern side of the valley the Upper Primal slates occur between the limestone and the gneiss of the mountain.

On the south side of the valley about one mile west of Centre Valley the limestone appears to rest directly against the gneiss and dip towards it, (§ 103.)

At Limeport the limestone maintains a similar position, pitching eastward against the gneissic mountain (§ 55.)



Centre mark; Allentown station, U.S.C.S.

There is no positive evidence of the Potsdam or Upper Primal slates at either of these localities.

Between Durham P. O. and the Delaware river the southern edge of the limestone appears to rest directly against the feldspathic gneisses.

Along the northern edge of this limestone area fragments of Potsdam quartzite and decomposed hydro-mica slate occur.

At one point west of Durham P. O. limonite is mined, (§ 222.) The ore occurs in decomposed hydro-mica slates. The mine is about 200 ft. above the base of the mountain.

Hudson River slates.

Slates overlying the limestone occur in only one locality within the mountain belt between the Berks county line and the Delaware river.

At Limeport about 30 feet of slates are exposed *over* the limestones at the quarries, (§ 55.)

The slate is somewhat different in character and a darker color than the Upper Primal slates, which underlie the limestones and overlie the Potsdam.

The slates of Limeport can be traced for a distance of about a mile northward on the east side of the creek. The slates occur loose in the soil.

There is apparently no gradation of limestone into the slate at the exposure at Limeport. The slate *rests directly upon* more or less massive limestone.

From the position of Newmeyer's mine (§ 56) it would appear that the limonite is found in decomposed slates, equivalent to those *overlying* the limestone at Limeport; but inasmuch as fragments of Potsdam quartzite are found a short distance south-west of Limeport, near the edge of the limestone (§ 59) it is possible that the limonite may belong to the horizon of the Upper Primal slates. The apparent dip of the limonite deposits in all cases is in all probability due to the infiltration of the limonite in lines of cleavage planes and does not represent the bedding of the slate.

Zinc ore occurs in the limestone at Friedensville. (See

§ 149.) The present mine is located on a regularly pitching monoclinal. The ore is blende. According to Rogers, p. 101, the old mine, which is ½ mile north of the present mine, is located on a synclinal fold. Mine abandoned.

Trap is found in two places north-east of New Zionsville. (§§ 66, 132.)

No evidence of a dyke is visible on the surface, although it probably exists.

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